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HELICOPTER DRIVE SYSTEM ON-CONDITION MAINTENANCE CAPABILITY (UH-1/AH-1)

BELL HELICOPTER COMPANY

PREPARED FOR
ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY

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HELICOPTER DRIVE SYSTEM ON-CONDITION MAINTENANCE CAPABILITY (UH-1/AH-1)

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were performed to determine if any part or assembly failure modes would limit on-condition maintenance capability.

This report concludes that UH-1/AH-1 helicopter drive system components have a capability for replacement for overhaul on an on-condition basis and that the overhaul intervals could be extended for some components or eliminated for others.

The report includes recommendations for further study.

PREFACE

This investigation of on-condition maintenance capability for helicopter dynamic subsystems was performed under Contract DAAJ02-74-C-0060 for the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia. The study was conducted under the technical direction of Victor Welner of the Military Operations Technology Division.

The principal design investigative work was conducted by Mr. George E. Knudsen of the Bell Helicopter Company Engineering Department. Many other members of the Bell Helicopter Company Engineering Department contributed significantly to this program; the author wishes to acknowledge especially Messrs. C. E. Braddock, O. L. Hensley, J. P. Keating, and R. L. Pascher.

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1.0 INTRODUCTION

Under an earlier contract with the Eustis Directorate, it was determined that the performance of CH-47C helicopter transmissions overhaul on an on-condition basis would be more cost effective than the current procedure, which establishes a maximum operating time between overhauls (TBO). From Reference 1, Mr. Dougherty concluded:

> As a result of this study it is evident that on-condition operation for helicopter transmissions would be extremely cost effective. In almost every case imaginable, the on-condition transmission would generate lower costs with little degradation of performance when compared to a transmission operated with a TBO.

Having put the cost question to rest, Mr. Dougherty further stated:

> Thus, the entire on-condition question really reduces to a safety issue: can state-of-the-art transmissions be operated safely in the 1000- to 5000-hour regimes?

Since the conclusions reached in the study reflect the operational experience of the CH-47, analysis of other helicopter systems experience was needed to formulate a clear position on helicopter component on-condition maintenance and to identify those design concepts and procedures which would most significantly enhance this approach.

This study assesses the capability of certain helicopter dynamic components to operate with no scheduled overhaul periods. It considers the following components on UH-1 and AH-1 series helicopters.

- Main Transmission
- Intermediate Gearbox
- Tail Rotor Gearbox
- Main Rotor Hub
- Swashplate and Support

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[1] Dougherty III, J. J., and Blewitt, S. J., ANALYSIS OF CRITERIA FOR ON-CONDITION MAINTENANCE FOR HELICOPTER TRANSMISSIONS, USAAMRDL Technical Report 73-58, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, September 1973, AD 773024.

Table 1 shows the part numbers, Federal Item Identification Numbers (FIIN), which are the last seven numbers of the federal stock number, and current effectivity of these assemblies.

The general approach used was to examine the overhaul and accident records, the inspection procedures, and the functional capability of the caution and warning subsystem and its condition-monitoring devices to determine if there is any part or assembly failure mode which limits on-condition maintenance capability.

The sources of data used in the analysis were:

- The Army Maintenance Management System (TAMMS)[2] DA2410 form, Component Removal, and Repair and Overhaul Records, Copies 1, 3, 4, 5, and 6

- Disassembly Inspection Summary records (SAV-634 forms)[3] of component overhaul

- The U. S. Army Agency for Aviation Safety (USAAAVS) accident report[4] records on UH-1 and AH-1 aircraft

- U. S. Army Depot Maintenance Manuals for UH-1 and AH-1 aircraft listed in Table 2

- U. S. Army preventive maintenance checklists for UH-1 and AH-1 aircraft listed in Table 2

Table 3 lists the number of records available in the DA2410 data file for analysis.

All figures and tables referred to in this basic report are arranged following Section 6.0, RECOMMENDATIONS.

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[2]Anon., THE ARMY MAINTENANCE MANAGEMENT SYSTEM (TAMMS), Department of the Army Technical Manual, TM 38-750, Headquarters, Department of the Army, Washington, D.C., November 1972.

[3]DISASSEMBLY AND INSPECTION SUMMARY - USE OF FORMS TO REPORT EVALUATION DATA, Special Quality Procedure 200.4.8, Bell Helicopter Company, Fort Worth, Texas, June 15, 1974. (This procedure in turn references AVSCOM Memo 335-5 - INSTRUCTIONS FOR COMPLETING SAV FORM 634.)

[4]ACCIDENT REPORTING AND RECORDS, Army Regulation AR385-40, Headquarters, Department of the Army, Washington, D.C., October 29, 1969.

2.0 APPROACH

2.1 BASIC CONSIDERATIONS

Components with scheduled TBO intervals are normally operated until their scheduled overhaul interval has expired or until some unsatisfactory condition is observed by the crew during flight or by maintenance personnel during inspection, or is signaled by the condition-monitoring and/or caution-warning devices. Therefore, during the interval between installation and the time the TBO interval has been expended, if the components are not permitted to complete their overhaul interval, they are removed prematurely "on condition." If there are no failure modes which cause abrupt functional failure of the assembly without prior deterioration symptoms which are adequate to signal an unsatisfactory condition while the assembly is still functioning safely, then it is conceivable to extend the scheduled TBO interval indefinitely and rely exclusively on these inspection and warning methods to signal the replacement of the assembly.

Since the on-condition maintenance capability exists and indeed is relied on to ensure safe operation of the drive system components from the time of installation to the scheduled time for overhaul, the approach of this study is to examine how well these methods may assure safe operation of these components if the TBO interval is extended or eliminated altogether.

2.1.1 Condition Evaluation

The current inspection procedures, condition monitoring, and warning systems, if adhered to, appear to be adequate to monitor the condition of the drive system components from time of installation to the scheduled time for removal without permitting a condition to occur which would jeopardize flight safety. Indeed, they were established as such to provide safe flight.

The procedures for daily, intermediate, and periodic inspections enable organizational maintenance personnel to observe the extent of inherent failure mode deterioration of the main rotor hub and swashplate, the oil leakage rate of the transmission, gearboxes, and UH-1D/H hub assemblies, and the presence and characteristics of debris collected at the chip detectors and filters. The procedures also enable the personnel to observe the result of some of the induced failure modes.

Transmission oil temperature and pressure are monitored with systems which have gages on the instrument panel. The impending bypass or bypass condition is signaled by an indicator on the oil filter. The presence of chips on the chip detectors is monitored by the warning system for the transmission and tail rotor gearboxes. During flight, the flight crew is signaled by the warning system when the transmission oil pressure is too low, the transmission oil temperature is too hot, or if the transmission, 42-degree gearbox, or 90-degree gearbox chip detector systems detect the presence of chips.

Of course, the inspection process relies on the ability and judgment of the maintenance personnel to observe the extent of wear and degradation, to recognize when conditions are no longer acceptable, and to replace components when necessary. The current automatic diagnostic and prognostic system (AIDAPS) studies[5] are endeavoring to determine what additional inspection and condition monitoring techniques would improve maintenance personnel capability. Since very few gears and bearings with significant deterioration have been removed from the UH-1 and AH-1 transmission and gearboxes during overhaul, engineers on the AIDAPS program have had considerable difficulty in locating parts suitable for their tests and analyses. It has been necessary to take parts replaced during overhaul and artificially degrade them. This experience further supports the assumption that transmission and gearboxes are being removed for condition too early. Vibration-sensing systems are being examined to see whether they, supplementing the chip detectors, can better identify the appropriate time for the replacement action; that is, whether the action must be done immediately or can be scheduled for the next intermediate or periodic inspection time.

2.1.2 Potential Problems With Component Overhaul to a TBO

Dougherty and Blewitt,[1] in their discussion of the relationship between on-condition maintenance operation of transmissions and reliability, safety, maintainability, availability, and cost, made some observations concerning the potential for failure of components with assigned TBO's. They compared two conditions for a component: (1) where the component is allowed to operate without time limit, and (2) where a TBO is established. Due to the particular hazard function of transmission

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[5]Contract DAAJ01-71-A-0035(P2B), Delivery Order 0007(P2B), TEST CELL DATA COLLECTION & TECHNICAL SUPPORT, developmental work in support of the Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) Advance Prototype Development, U.S. Army Aviation Systems Command, St. Louis, Missouri, May 30, 1973.

assemblies in their study, in the second condition, for scheduled removals, a greater potential for failure is present due to the exposure to the high failure rate, infant mortality portion of the hazard function. Because of this, the number of failures observed over a fleet life cycle could be greater in the second condition where the TBO was imposed. The frequency of exposure to the infant mortality portion of the hazard function would be much less for the component allowed to operate without time limit.

2.1.3 Factors Supporting Recognition of On-Condition Maintenance Capability

One of the major factors supporting the recognition of on-condition maintenance capability of the five drive system components is the complete lack of control that exists during the overhaul process with regard to the accumulated time on the parts installed in the assemblies. During the early part of this study, one of the areas to be investigated was the parts replacement characteristics as assemblies went through initial and subsequent overhaul. The overhaul component disassembly inspection summary reports were researched to locate the records of sequential overhaul of assemblies identified with the same serial number. The purpose of this area of investigation was to determine a measure of the time-to-replacement distribution of the dynamic parts installed in the assembly when it was new. This information could show the long life potential for the parts, which in turn could support the contention that an on-condition maintenance capability existed for the assembly. It was only after this phase of the analysis had been completed that a more significant factor emerged from the research activity. It was determined that the analysis approach to trace parts replacements beyond the first overhaul was not valid. During the overhaul process after the assembly is disassembled and the parts condition inspection has been completed, the parts are put into stock bins. Then, when the assemblies are reassembled, the parts required are drawn from the bins indiscriminately. This means that an assembly can be rebuilt using all new parts, all old parts, or any mix of old or new regardless of the parts rejected during the initial teardown and inspection. This means there is no relationship between assembly time since new, and the age of parts installed within the assembly. From this, one must conclude that the assembly is already essentially relying on condition monitoring to maintain safe operation.

A potential safety problem was found to exist when it was determined that this parts replacement process also applied to the main rotor hub and swashplate as it did to the transmission and gearboxes for which it was initially observed. Although records are painstakingly kept of the accumulated time since new and since overhaul for the total assembly, no records are maintained to track the accumulated time since new for the parts with specified retirement intervals. The analysis of the overhaul disassembly inspection summary records substantiated that the specified retirement intervals for some of the life-limited parts were being ignored. Since this is occurring, it is strongly recommended that the basis for the scheduled parts retirement intervals be reexamined and if these part replacements are truly required for flight safety, then a better method of logging and tracking accumulated parts time is required. Also, some concern should be given to the assemblies which have been overhauled. These assemblies may have limited life parts installed which may exceed their retirement life.

A large percentage of components replaced at TBO were providing acceptable operation at the time of removal. Most of the parts replaced due to condition during overhaul of these assemblies, therefore, must have many hours of safe operation still unused. The extension of assembly operating time to a point where a condition warrants its replacement can save a great many parts operating hours.

2.2 FACTORS LIMITING THE PERFORMANCE OF THE STUDY

Certain factors have caused some difficulty in the performance of this study. They are:

- In the main, assemblies which are removed prior to their TBO for inherent failures have actually not failed.

- Nowhere in the overhaul process is any attempt made to substantiate the reason for premature removal.

- Parts replaced during overhaul are rejected due to condition or modification, not necessarily due to failure.

The following explains to some degree why these factors exist.

The whole purpose of the inspection procedure, condition monitoring, and caution-warning devices as applied to the drive system components is to recognize the time when inherent degradation is unacceptable while the component is still functioning. When the assembly is removed, a failure cause code is recorded. However, the failure code used relates to the assembly mode of degradation that is considered no longer acceptable by the maintenance personnel. Though this is called failure, it is most probable that the assembly is still operable.

The assemblies are also removed prematurely if they have been subjected to induced failure conditions. There again, the assembly is probably still operable, but the condition to which the assembly was subjected is such that special measures must be taken to assure safe operation. Copies of the special inspection requirements for the AH-1G components, typical of those for the UH-1 aircraft component, are shown in Appendix D.

Except for the swashplate, which is not an enclosed assembly, the organization maintenance personnel seldom can confirm the cause of the assembly degradation. Unfortunately, from an analysis standpoint, no action is taken during the overhaul process to confirm the cause of assembly removal.

All of the inherent failure mode conditions are occurring within an assembly concurrently. Since assembly inherent failure modes are, in the main, evidenced by gradual deterioration to a point where a condition exists which is no longer acceptable, only the one which, in the opinion of the maintenance personnel, is unacceptable is recorded as the cause for replacement. The degree to which the other modes exist is not recorded in the removal records nor can it be determined by the overhaul records. This last statement is equally true for assemblies removed for induced failure causes and for TBO.

While assemblies may be removed prematurely for failure mode, when assemblies are overhauled, the parts that are replaced (other than the normally replaced items, i.e., gaskets, bolts, etc.) are not examined for just failure, but also for condition. This is true for assemblies removed for TBO as well as for those removed for condition. It would be inconsistent to consider that the parts rejected during overhaul of an assembly removed for TBO had failed. The consideration used for parts rejection is not simply whether the part is unacceptable for further operation, but also whether the part's condition is such that it is suspected that it will deteriorate to an unacceptable condition within the next TBO interval. The basis for parts rejection during overhaul is recorded at some overhaul facilities. However, the severity of the condition and any secondary causes for rejection are seldom recorded. If the part is rejected during overhaul due to a modification change on the assembly, no record of the condition of the part is made. Seldom do the records indicate loss of a part's function.

In a concurrent research and development program in support of the Automatic Inspection, Diagnostic, and Prognostic System (AIDAPS) Advanced Prototype Development,[5] great difficulty has been experienced in obtaining gears and bearings of transmissions and gearboxes which were rejected during overhaul that have sufficient degradation to be observable with condition monitoring equipment within a reasonable time when installed in bench or air vehicle test systems. The greater majority of the parts replaced during overhaul had degradation so slight as to make them completely unusable for the AIDAPS test program. This was because of the operating time that would be required before the part degradation would become unacceptable for assembly operation based on an observable (by the condition-monitoring equipment) symptom. This means that many hours of useful life of parts rejected during overhaul are lost.

2.3 ASSUMPTIONS USED IN THE ANALYSIS

The analysis was based on several assumptions concerning:

- The operability of the assembly at the time of early removal due to inherent degradation

- The codes used to show cause of removal

- The codes which related to the more critical mode of assembly degradation

- The comparative percentage of parts replacement from the group of assemblies removed for the critical codes and the percentage of replacement from the sample of assemblies with records of sequential overhauls.

2.3.1 Assembly Operability

In the analysis it has been assumed that at the time an assembly was removed prior to TBO for an inherent cause of degradation, the assembly was still capable of providing safe operation. This assumption has been discussed in Section 2.2. One of the objectives of the analysis was to thoroughly test this assumption since, if it is false, the on-condition maintenance capability would not exist, not even during the interval between initial installation and the currently assigned TBO.

2.3.2 Assembly Removal Failure Cause Codes

It has been assumed that since:

- there is a very large number of failure cause codes in TAMMS,

- many of the codes have only a slightly different meaning from others in the code list,

- the coded failure causes are independently recorded by many individuals,

common modes of degradation may have been reported using several different failure cause codes.

This assumption has a corollary. The failure codes used to show cause for removal may be grouped into common failure modes.

Following these assumptions, the failure cause codes of the DA2410 computer tape records for each assembly removal were reviewed first to classify the codes into four major categories:

- Inherent failure modes

- Induced failure modes

- Nonfailure mode

- Unknown removal reasons

This was done by first evaluating whether each failure code description could be logically applied to the assembly. If not, the code was considered to be an unknown cause of removal. Next the nonfailure codes were identified. Those remaining were then reviewed to evaluate whether each failure description could only apply to an induced cause of failure. If so, the failure code identified an induced failure mode; if not, the failure code identified an inherent failure mode.

In the analysis it was assumed that the group of assemblies removed for unknown causes was similar to and would not significantly alter the proportional distribution of the assemblies with identifiable causes of removal.

The inherent failure codes were then grouped by the analyst into common failure modes as shown in Tables 4 through 8, using his judgment as to which codes were related.

2.3.3 <u>Critical Mode of Assembly Degradation</u>

If for a period the maintenance instructions were not adequately followed, perhaps under the stress of combat activity, then a more serious mode of assembly degradation could occur. Using this assumption, one of the groups of failure cause codes has been selected as the potentially critical assembly failure mode. The failure mode selected would include any operational failures of the assembly. The overhaul records of a group of assemblies with these failure codes were used to compute the parts replacement percentages for comparison with the parts replacement percentage similarly computed for the sequential overhaul assemblies.

2.3.4 Critical Part Identification

If any part of the assembly has a critical failure mode, one which could cause the assembly to cease to function, it has been assumed that the parts percentage replacement during overhaul would be significantly greater for the assemblies removed for sequential overhaul. A comparison of the replacement percentages guided the selection of the parts for which the failure modes and effects analysis was performed.

2.4 ANALYSIS FLOW PROCESS

2.4.1 Component Removal Records Analysis

This analysis provides an evaluation of drive system component inherent failure mode distributions.

2.4.1.1 Data Source

The data used for the component removal records analysis were from the Army Maintenance Management System (TAMMS)[2] Component Removal and Repair/Overhaul Record (DA Form 2410) data. TAMMS data are received monthly by the Bell Helicopter Company (BHC) Reliability Data Group on magnetic tape. The tape records contain information such as component serial number, hours since new, hours since last overhaul, number of prior overhauls, and reason for removal, which can be used to estimate the distribution of assembly time at removal.

2.4.1.2 Preparation of TAMMS 2410 Data for Analysis

Special component data files are created by choosing selected assemblies from the TAMMS 2410 master file of BHC helicopter components. For example, one data file contains main rotor hub data, another main transmission data, etc. The master tapes are searched for the selected assemblies by means of the Federal Item Identification Number (FIIN), which is the last seven digits of the Federal Stock Number (FSN). Each of the data files contains all the data from each of the number 1, 3, 4, 5, and 6 copies of the DA 2410 form.

Each 2410 tape record contains a large amount of information not germane to the component removal analysis. Also the data pertaining to a particular removal occurrence are contained on records created from copies 1, 5, and 6. A new data file was created for each of the assemblies by choosing selected data fields from copies 1, 5, and 6 and consolidating the information onto one data record for each removal occurrence. Each composite record thus contains removal, repair, and reinstallation information for each removal occurrence.

For the component-removal analysis, the most recent information available just prior to each overhaul is needed. Accordingly, an additional data file was created from the composite record data file by choosing the highest hours since last overhaul value for each unique combination of component FIIN, component S/N, and number of prior overhauls value. For zero prior overhauls, we define the hours since last overhaul as the hours since new, and this information is used in the hours since last overhaul data field. The removal records thus obtained are as near to each assembly's next overhaul as is possible to obtain.

The data were then sorted into the following sequence for each group of assemblies being analyzed: (1) reason for removal or failure code, and (2) hours since last overhaul for assemblies with zero prior overhauls. The analysis was performed separately for assemblies with zero prior overhuals and for assemblies with one or more prior overhausl. Records with blank or zero removal times were discarded. Records with failure code 645, which indicates spurious time values, were discarded. Records with hours since last overhaul greater than the TBO value of the assembly plus 500 hours were discarded as being in error.

A count of the number of removals in each 100-hour increment of component life was determined for each removal reason for each different analysis being performed. See Section 2.5.1, Hazard Rates, for the mathematical technique used to derive failure modes hazard rate estimates from these removal reason record counts.

Figure 1 presents a flow chart for the preparation of TAMMS 2410 data for the analysis process.

Tables 9 through 15 show how the removal records for each of the assemblies were grouped by reason for removal.

2.4.2 Component Overhaul Records Analysis

This analysis provides an indication of the capability of the parts of an assembly to survive through multiple overhauls. It also shows that putting the assembly on condition should not require longer operation of the parts than what they are already achieving. However, the parts may acquire a longer average life by putting the assembly on condition.

An investigation of the current methods being used during component overhaul revealed that there was no traceability of those parts that are found to be good during teardown. This investigation was conducted through interviews of BHC transmission overhaul and inspection personnel and telephone conversations with Quality Assurance personnel at the U.S. Army Aeronautical Depot Maintenance Center (ARADMAC). Therefore, based on this information, there is no way of determining the age of a "good used part" being used on the buildup of an assembly after it has been through its first overhaul. This investigation was required as an initial step to provide insight into the overhaul process being used, so that a better understanding and interpretation of the findings could be made.

The largest single task of this analysis was the hand-sorting of all in-house SAV634 records[3] for each component being reviewed. The sorting was of the serial numbers of the components and was performed to identify the sequential overhauls. From this, a Sequential Overhaul List (see Figure 2) was prepared for each component. Data on this list included the overhaul number, initial/subsequent serial numbers of the components, time since new, time since last overhaul, the removal cause, and the data source (either from a computer listing or from the record forms). In addition to being used to identify those serial numbers that had sequential overhauls, this list was used to distinguish any erroneous information or inconsistencies between subsequent overhauls that may require a particular entry to be eliminated.

In order to identify those items for each component assembly for which a parts replacement analysis was performed, the following tasks were accomplished:

- A list of all parts was made for each assembly being reviewed.
- From this list, all standard replacement items (i.e., nuts, bolts, seals, etc.) were removed.
- Finally, those remaining items that, in the opinion of the analyst, did not perform a dynamic function or contain a failure mode which could cause loss of function of the assembly and result in a safety-of-flight condition were removed. The remaining, plus any additional parts included in the replacement record due to assembly modifications that were not excluded by the above criteria, formed the final list of parts for the assembly analysis.

Once these parts were identified for each assembly, they were entered by part number in alphanumeric sequence for each assembly on the form displayed in Figure 3. The number of parts replaced per overhaul was recorded for each serial-numbered assembly in the Sequential Overhaul List for each part number. The Failure Code, Time Since New, and Time Since Last Overhaul were also entered for ease of correlation analysis.

Finally, the number of parts replaced per overhaul type (i.e., first, second, third, fourth) were summed for all serial numbers of each assembly. Since there were insufficient data in the third and fourth overhauls to warrant separate analysis, these two were grouped with the second overhauls into one classification. Once this was accomplished, the percent-parts-replacement calculations were made for the first overhauls and for the second and subsequent overhauls for each part with data available.

An analysis of the percentage of parts replaced at overhaul due to critical failure modes was performed next. A search of all SAV634 files, including the newer record forms, older computer listings, and microfilm of the older data, was made. The data from all records with the following removal codes were extracted as appropriate for each of the assemblies:

- Mechanical Binding (040)
- Controls Inoperative (114)
- Binding (135)
- Jammed (370)
- Internal Failure (374)
- Seized (840)

As before, the number of replacements per part number was entered on a form similar to that presented in Figure 3. Also, for the analyses, the condition of the parts (worn, pitted, scored, etc.) was noted. This information was used as input for the failure mode and effects analysis. A summation of the number of parts replaced by part number for each assembly, along with its respective percent-parts-replacement calculation, was made. This analysis was based on the above failure codes since they relate to an assembly failure mode which results in loss of assembly operation.

2.4.3 Accident Data Analysis

This analysis is performed to determine whether there are any failure modes of the assemblies that can impair flight safety or that can occur without having degradation symptoms which could have been previously observed by maintenance personnel and/or the flight crew.

If any part of an assembly has a failure mode which has been suspected of causing an assembly failure and which has resulted in a forced landing or more severe mishap, the part and its failure mode are included in the failure modes and effect analysis.

BHC has received records of UH-1/AH-1 mishaps from the Army since 1963. These data are supplied by the U.S. Army Agency for Aviation Safety (USAAVS), formerly U.S. Army Board for Aviation Accident Research (USABAAR). These data were initially received on IBM cards; now they are received on magnetic tape. There have been three different formats of these cards since 1963. The first format was effective through 31 December 1966. The second format was used for data obtained from 1 January 1967 through 31 March 1971. The current format became effective 1 April 1971. The data period selected for this analysis is 1 January 1967 through 31 March 1971.

The mishap records consist of a series of codes and a brief narrative description of the mishap. The mishap classification, aircraft system or component involved, and whether the component involved had a failure or malfunction are given in code form.

There are six mishap classifications:

Class 1 - Major damage - total loss

Class 2 - Major damage - repairable

Class 3 - Minor damage

Class 4 - Incidental damage

Class 5 - Forced landing

Class 6 - Precautionary landing

Classes 1 through 5 mishaps are defined for this analysis as occurrences which degrade flight safety since they are beyond the discretion of, and with perhaps limited control of, the crew. Class 6 mishaps, the precautionary landings, are performed at the discretion and under the control of the crew.

They are considered to be mishaps that do not degrade flight safety.

The data for each model were sorted by mishap classification and the failure/malfunction code, and were counted to determine the total number of material failures for each aircraft model by mishap classification.

To determine the modes of failure for the components analyzed, a computer listing of the records for each of these components was obtained. The records were sorted by mishap classification code and the failure/malfunction code. For each mishap caused by a failure or malfunction of the component, the narrative was read to determine the mode of failure. The failure modes for each component were tabulated manually and grouped by aircraft model and the two major groups of mishap classification (those which degrade flight safety and those which do not).

2.4.4 Failure Modes and Effects Analysis

The purpose of the Failure Modes and Effects Analysis (FMEA) was to identify a part failure mode, if it exists, which could occur without sufficient, noticeable, gradual degradation of the assembly and would result in the loss of function of the assembly. All part failure modes and effects were considered in light of their significance as regards the assembly being placed in an on-condition maintenance environment.

The method of selection of parts shown in the FMEA has been described in Sections 2.3.4 and 2.5.3. In addition, parts which appeared potentially critical from accident data analysis failure mode descriptions were also analyzed. These parts were analyzed to see whether they could impair flight safety in the on-condition consideration.

The degradation conditions which were recorded for the parts which were replaced were found in the Disassembly Inspection Summary data. In addition, modes of part degradation and the symptoms and effects were supplied for the various parts by personnel consulted in the following Engineering groups:

- Transmission Design
- Rotor Design
- System Safety
- Service

The causes and effects of the part failure modes of the main transmission, 42-degree gearbox, and 90-degree gearbox in the FMEA were taken from USAAVLABS Technical Report 70-66.[6] The warning signals for the individual modes were supplied by transmission design personnel. The inclusion of the free-wheeling clutch assembly and other parts was the result of the accident data study. System Safety and Transmission Design personnel provided assistance for the failure modes, effects, and warning analysis for the freewheeling clutch assembly. In addition, articles by H. P. Troendly[7] and E. Kirchner[8] were reviewed for the FMEA on the freewheeling clutch.

Rotor Design and Service Engineering personnel provided assistance for the failure modes and effects analysis of the main rotor hubs and swashplate and support assemblies. The Rotors and Service personnel also assisted in identifying the warnings for the various part failure modes.

The various organizational level maintenance technical manuals were used as references for the analyses. In analyzing the overhaul data, ambiguous failure modes or descriptions were clarified by consultation with the overhaul personnel. Part removal criteria were also supplied by overhaul personnel. In addition, component drawings were employed to answer other questions.

2.5 MATHEMATICAL EVALUATION METHODS

2.5.1 Hazard Rates

2.5.1.1 Analysis Technique

The removal reasons were grouped into the following major categories: (1) inherent failure causes, (2) induced failure causes, (3) no failure causes, and (4) unknown causes. The

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[6]Bowen, C. W., Dyson, L. L., and Walker, R. D., MODE OF FAILURE INVESTIGATIONS OF HELICOPTER TRANSMISSIONS, USAAVLABS Technical Report 70-66, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, January 1971.

[7]Troendly, H. P., FULL PHASING FOR ONE-WAY CLUTCHES, Product Engineering, McGraw-Hill Publishing Company, Inc., New York, N.Y., December 1954.

[8]Kerchner, Engelbert, SPRAG CLUTCHES MAKE A COMEBACK, Aviation Age, New York, N.Y., January 1955.

individual inherent failure codes were grouped into subcategories. The number of removals in each interval for each removal reason was summed to obtain totals for each removal reason category. The analysis procedure was performed separately for first overhauls and all subsequent overhauls.

A sample from a population in which each assembly is operated until it is observed to fail is known as a complete sample. A sample in which some assemblies are removed for nonfailure causes before they have failed is known as a censored sample. If the removal time is known for all assemblies except for those removed at some upper limit, e.g., TBO or retirement life, then the data are said to be simply censored. If some of the censoring times are less than some of the failure times, then the data are said to be multiply censored. If the censoring times in multiply censored data occur at successive stages in the assembly's life, the data are said to be progressively censored. The censoring times can be random or fixed. An example of a random censoring time would be a main rotor hub that is removed to facilitate an unscheduled maintenance action on a main transmission. An example of a fixed or predetermined censoring time would be an assembly removed for a scheduled maintenance action or one removed for time change. Censored items are referred to variously in the literature as losses, withdrawals, dropouts, etc. The assembly removal data that have been analyzed are progressively multiply censored with both random and fixed censoring times. Assemblies removed for unknown causes are treated as censored items in the hazard rate analyses. The following is the mathematical technique for handling censored data.

2.5.1.2 Mathematical Model

There are several techniques for analyzing censored data. The method of Kaplan and Meier[9] and the method of Nelson[10] are both based on estimation of conditional probabilities given survival to some time, t. The following procedure is essentially Nelsons' method but has been modified in order to handle grouped data. The steps in the analysis are as follows:

First, the number of assemblies surviving at the beginning of each 100-hour interval is determined.

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[9]Kaplan, E. L., and Meier, Paul, NONPARAMETRIC ESTIMATION FROM INCOMPLETE OBSERVATIONS, American Statistical Association Journal, June 1958, pp. 457-481.

[10]Nelson, Wayne, HAZARD PLOTTING FOR INCOMPLETE FAILURE DATA, Journal of Quality Technology, Volume 1, No. 1, January 1969, pp. 27-52.

$$n_i = N - \sum_{k=1}^{i-1} \left(r_k + c_k\right) \tag{1}$$

where

N = total number of assemblies in the sample

n_i = number of survivors at the beginning of the ith interval; i.e., conditional sample size

r_k = number of failure removals during the kth interval

c_k = number of items lost from observation or censored during the kth interval

The conditional sample size can also be determined recursively from the previous conditional sample size by subtracting the combined number of failures and censored items in the previous interval.

$$n_1 = N$$

$$n_i = n_{i-1} - \left(r_{i-1} + c_{i-1}\right) \tag{2}$$

Consider an assembly capable of failing from m different modes. Let r_{ij} be the observed number of failures in the ith interval due to mode j. The total number of failures in the ith interval is given by

$$r_i = \sum_{j=1}^{m} r_{ij} \tag{3}$$

The hazard function h(t) is given by[10]

$$h(t) = \frac{f(t)}{R(t)} \tag{4}$$

where

$f(t)$ = probability density function

$R(t)$ = reliability function

and is the conditional probability of failure density at time t given that failure has not occurred before then.

The average failure rate for some time interval is defined as the total number of failures occurring during the interval divided by the total time accumulated on all components operating during the interval. Since the hazard function is the instantaneous failure rate at time t,[10] we may estimate the hazard function by using the failure rates for sequential time intervals. The hazard function is treated as if it were constant for each time interval, and the failure rate estimate is used to represent the hazard function. To determine this estimate, the total time accumulated on all of the components during each time interval needs to be estimated.

If all failure and nonfailure removals occur at the end of the ith interval, the total time accumulated by the components during the interval would be $n_i \Delta t$, where Δt is the length of the interval. If all of the removals occur at the start of the interval, then the total time accumulated by the components during the interval would be $(n_i - r_i - c_i)\Delta t$. The simplest and most logical assumption for grouped data, in the absence of any other information, would be that the removals are more or less uniformly distributed throughout the interval. Thus, the total time accumulated by the components is approximately equal to the average of the above two estimates or $\left[n_i - (r_i + c_i)/2\right]\Delta t$. An estimate for the hazard function for the ith interval due to the jth failure mode is given by

$$h_{ij} = \frac{r_{ij}}{\left[n_i - \frac{r_i + c_i}{2}\right]\Delta t} \tag{5}$$

From equation (3), it follows that

$$h_i = \sum_{j=1}^{m} h_{ij} \tag{6}$$

That is, the total hazard rate is simply the sum of the modal hazard rates.

This equation provides a nonparametric estimate for the hazard function which can be plotted as a histogram in a manner analogous to that used in plotting the probability density function derived from observed sample data. Since the cumulative hazard function at time t is defined by

$$H(t) = \int_0^t h(u)\, du \tag{7}$$

it follows that a nonparametric estimate for the cumulative hazard function at t_i due to mode j can be obtained by summing areas of the rectangles of the hazard function histogram from 1 to i.

$$H_{ij} = \sum_{k=1}^{i} h_{kj}\Delta t = \sum_{k=1}^{i} \frac{r_{kj}}{\left[n_k - \frac{r_k + c_k}{2}\right]} \tag{8}$$

From equation (3), it follows that

$$H_i = \sum_{j=1}^{m} H_{ij} \tag{9}$$

A nonparametric estimate simply means that no assumptions have been made as to the true nature of the underlying probability distribution. The hazard function histogram will probably show random fluctuations from one interval to the next. The data can be smoothed by assuming that a particular parametric representation of the distribution holds. A useful distribution for this approach is the three-parameter Weibull distribution. The cumulative hazard function H(t) for this distribution has the following form:

$$H(t) = \left(\frac{t - \gamma}{\theta}\right)^{\beta} \tag{10}$$

where

β = shape parameter

θ = scale parameter

γ = location parameter

The parameter β determines the shape of the Weibull curve, while θ provides a scaling effect on the curve. The parameter θ is also known as the characteristic life since the percentage of items failed at $t = \theta$ is 63.2 percent, and is independent of the parameter β. The parameter γ indicates the starting point of the distribution before which no failures can occur.

When $\gamma = 0$ the distribution reduces to the two-parameter Weibull distribution. This distribution provides a good fit to most of the data. For some failure modes, for which the data showed no failure removals during the first 100-hour time interval, a better fit was obtained by setting $\gamma = 100$ hours. In the analysis there was no way to determine from the data the reason for the apparant shift of the failure mode distributions where they occurred.

If we take the natural log of both sides of Equation (10), we obtain

$$\ln H(t) = -\beta \ln \theta + \beta \ln(t - \gamma) \tag{11}$$

If we let

$$Y = \ln H(t) \tag{12}$$

$$X = \ln(t - \gamma) \tag{13}$$

$$A = -\beta \ln \theta \tag{14}$$

and

$$B = \beta \tag{15}$$

we see that Equation (11) becomes

$$Y = A + BX \tag{16}$$

Since Y is a linear function of X, the transformed data should plot as a straight line on regular square grid paper. Since $\beta = B$ is the slope of the line, the parameter β is frequently referred to as the Weibull slope. To avoid making the logarithmic transformation, a special plot paper called Weibull hazard paper has been developed which allows one to plot H(t) versus $(t - \gamma)$ directly. A straight line can then be drawn through the points by eye. The paper is actually log-log with two auxiliary scales provided. The upper auxiliary scale is used to estimate β, and the second auxiliary scale gives the probability of failure in percent for the corresponding cumulative hazard percentage. The parameter θ is estimated as the value of $(t - \gamma)$ on the straight line corresponding to 100 percent cumulative hazard; or, equivalently, 63.2 percent failed.

The parameter γ is usually estimated by trial and error. Several values of γ are tried and the one which produces the most nearly linear plot is used as the estimate.

Rather than estimate the line by eye, which gives only a subjective fit, the method of least squares was used to estimate the parameters A and B from which we get β and θ as follows:

$$\beta = B \tag{17}$$

$$\theta = e^{-A/B} \tag{18}$$

The hazard plots in Appendix A show that the assumption of a Weibull distribution is reasonable and facilitates further analysis of the data.

Having determined β, θ and γ, the reliability function at time t for the three-parameter Weibull distribution is given by

$$R(t) = e^{-H(t)} = e^{-\left(\frac{t - \gamma}{\theta}\right)^{\beta}} \tag{19}$$

An estimate of the mean-time-between-removals (MTBR) for both premature removals and TBO removals can be obtained from the equation

$$MTBR = \int_{0}^{T} R(t)dt) = \gamma + \int_{\gamma}^{T} e^{-\left(\frac{t - \gamma}{\theta}\right)^{\beta}} \tag{20}$$

where T = TBO of the assembly.

Equation (20) can be evaluated in closed form only for $\beta = 1$, yielding the result

$$MTBR = \gamma + \theta \left[1 - e^{-\left(\frac{t - \gamma}{\theta}\right)^{\beta}} \right] \tag{21}$$

If, in addition, $\gamma = 0$, then Equation (21) reduces to the usual result for the exponential distribution where θ = MTBF of the failure distribution.

In general, Equation (20) must be evaluated numerically by some procedure such as Simpson's rule.[11]

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[11] McCracken, Daniel D., and Dorn, William S., NUMERICAL METHODS AND FORTRAN PROGRAMMING, John Wiley and Sons, Inc., New York, 1964, pp. 160-193.

2.5.2 Parts Replacement Calculations

The calculations for the percentage of parts replaced at first overhaul, for those replaced at second and subsequent overhauls, and for those replaced due to critical failure modes were based on the following equation:

$$\text{\% Replaced} = \frac{\text{No. Replaced}}{(\text{Quantity per Assy}) \times (\text{No. of Assy's})} \times 100 \qquad (22)$$

where

No. Replaced = total number of parts found to be replaced for each type of overhaul (first, second and subsequent, and due to critical failure modes)

Quantity per Assy = total number of a particular part per those specific assemblies reviewed in the analysis

No. of Assy's = this is the total sample size of the SAV634 records reviewed for a particular assembly.

2.5.3 Identification of Parts for Failure Mode Study

The study of the parts replacement history determined the percentage of the functioning parts by part number that were replaced from three groups of assemblies:

- Assemblies being overhauled for the first time
- Assemblies being overhauled for the second or subsequent time
- Assemblies being overhauled which had one of the critical group of failure codes recorded as reason for removal

Parts were selected for the failure mode study on the basis of the results of the parts replacement analysis by using the following procedure. Note that no part was omitted from the analysis simply because the percentage replaced from the assemblies with critical failure codes was small.

First, the percentage replacement from the assemblies with critical failure codes was denoted as P_c. Next, the average percentage replacement at overhaul, $\bar{P}_o$, was calculated by

$$\bar{P}_o = \frac{N_1 P_1}{N_1 + N_2} + \frac{N_2 P_2}{N_1 + N_2} \tag{23}$$

where

N_1 = number of first overhaul assemblies

N_2 = number of second and subsequent overhaul assemblies

P_1 = percentage of the parts replaced at first overhaul

P_2 = percentage of the parts replaced at second and subsequent overhauls

The percentage replaced at first overhaul and the percentage replaced at second and subsequent overhauls can be found in tables in Section 3.2. N_1 and N_2 can be found in the footnotes of the same tables.

The ratio R_s was computed by

$$R_s = \frac{P_c}{\bar{P}_o} = \frac{\text{Percentage replaced due to critical failure modes}}{\text{Average percentage replacement at overhaul}} \tag{24}$$

Components to be analyzed in the Failure Mode Analysis were then selected by the following critieria:

- If the ratio R_s equaled or exceeded 1
- If the product of the ratio R_s and the percentage replaced due to a critical failure mode, P_c, equaled or exceeded 50.

The first selection criterion was used since it would select any part which was replaced more often from assemblies removed for potentially critical failure-coded causes than from the average assembly overhauled. The second criterion was more arbitrarily established. Its objective was to select parts which have a large percentage of replacement during overhaul of the critically coded assemblies even though the percentage is still somewhat less than the parts overhaul average percent replacement at overhaul.

The remaining parts are considered to have been shown to have adequate life and safe operation by their continued high percentage of reinstallation such that a failure mode and effect analysis on them would be unnecessary.

3.0 ANALYSIS RESULTS

The general results of the analyses indicate that assembly modes of degradation occur concurrently and proceed until either one of the modes becomes unacceptable or the TBO interval has been expended, at which time the assembly is removed for overhaul. This process may be interrupted by an externally caused situation or condition which will necessitate removal for overhaul or scrap. The unacceptable level of degradation occurs prior to any mode which would cause loss in function.

All the dynamic parts of the assemblies reviewed for parts replacement during overhaul had at least a percentage that survived for reinstallation in an overhauled assembly.

Although there were some records in the accident data which attibuted material failures of the five dynamic components to forced landings or worse situations, on analysis of the narrative record and the mode reported, it was concluded that the component failure either was secondary to some other primary cause, was charged as the accident cause when only suspected, or resulted from inadequate maintenance.

Only a few of the dynamic parts of assemblies removed for a coded failure cause which could be potentially critical showed a significant increase in percentage of replacement during overhaul over the percentage replaced during overhaul of the assemblies reviewed for consecutive overhaul. Failure mode and effects analyses of these parts revealed no modes which could degrade to an unsafe condition without producing symptoms which would be adequate to provide for safe replacement of the assembly. This was also true for parts mentioned in the accident data narratives which did not show a higher percentage of replacement.

3.1 COMPONENT REMOVAL DATA

Tables 9 through 15 show that although a large percentage of the assembly removals were for unknown causes, the number of assembly removals for inherent causes were more than adequate to provide significant results for the inherent failure mode hazard rate analyses. It was assumed in the analysis that the group of assemblies removed for unknown causes was similar to and would not significantly alter the proportional distribution of the other causes of assembly removal. For time values less than the time of their removal they were treated as part of the operating population for the Weibull Analyses.

Table 16 shows the Weibull distribution parameters for the combined failure cause removals of assemblies for overhaul. It shows the MTBR resulting from the removal distribution and the scheduled TBO. Figures 4 through 10 present plots of these distributions on Weibull probability paper.

Table 17 shows the Weibull distribution characteristics which were obtained for each assembly type inherent-failure-coded cause of removal for overhaul. It shows separately the results for the removals for first overhaul and for the second and subsequent overhauls. It also shows the characteristics for the combined distribution of all inherent failure modes. Although for some failure modes there was a higher characteristic life for previously overhauled assemblies, the characteristic life for the combined inherent failure mode distributions for all assemblies was greater for the assemblies not previously overhauled. The percentage that the characteristic life differed varied from about 5 percent for the Model 540-type swashplate to 63 percent for the 90-degree gearbox. In no case did the shape parameters (β) of the individual inherent failure mode distributions exceed 1.9, and 75 percent of the distributions had shape parameters equal to 1 ±0.4. In no case were the higher-valued shape parameters (that are characteristic of bearing and gear failure distributions*) apparent in the analysis results. This suggests that the extent of degradation necessary to consider that the bearing or gear has failed may be considerably more extensive than the bearing or gear degradation necessary to cause assembly replacement.

The plots of the cumulative hazard analysis are in Appendix A.

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*Gears in BHC transmission have shape parameters in the region of 5 to 5.5 while steel bearings as a class have shape parameters 3.7 to 4.0. Examples of these shape parameters have been shown by C. W. Bowen in "Analysis of Transmission Failure Modes," paper 710454 presented at SAE National Air Transportation Meeting, Atlanta, Georgia, May 1971, and D. V. Sundberg in "Ceramic Roller Bearings for High Speed and High Temperature Applications," paper 740241 presented at SAE Automotive Engineering Congress, Detroit, Michigan, February 1974.

3.2 COMPONENT OVERHAUL ANALYSIS TO DETERMINE PARTS REPLACEMENT PERCENTAGE

The component overhaul analysis revealed several significant results.

- Except for a few parts, there is a good probability that the parts will survive more than two assembly overhauls.

- Prior to early 1974, when the number of assemblies being overhauled per year was large, the parts removed during the overhaul process that were inspected and found to be acceptable lost identity with the assemblies from which they were removed. The parts were stored with like parts. During reassembly, parts were drawn from this stock for installation. After assembly, the only part of the assembly which would have the same time since new as that recorded for the assembly was the part onto which the assembly serial number was bonded. This situation may make the next item an even more difficult problem to evaluate, and if necessary, to correct.

- The records indicate that for even the relatively small sample of assemblies examined, some life-limited parts have been reinstalled in hub and swashplate assemblies and will exceed their retirement life therein.

Tables 18 through 28 show the percentage of the parts by part number that were replaced during the first overhaul and at second and subsequent overhauls. The assembly part numbers are those that the assemblies were configured to at the last recorded overhaul. The percentage of the parts replaced from assemblies removed for critical failure codes is shown so that the parts with a significant difference in replacement percentage can be identified for further study.

Table 29 shows the mean time to removal (MTR) values for the sequential overhaul sample. The MTR of the assemblies at the second overhaul was consistently less than the MTR at the first overhaul.

The parts listed in Tables 18 through 28 are in general those thought to have an operational function in the assembly. The percentage replaced during overhaul was low for most of the parts. This means that at least some of the parts continue to operate and maintain an acceptable condition for multiple overhaul periods and provide no limitation to on-condition maintenance capability.

The following identifies a potential part reinstallation problem for some of the assemblies. A recommendation covering this problem is presented in Section 6.

Only 60 percent of the 204-011-113-1 straps were replaced during the second overhaul of the 204-011-101-9/-11 main rotor hub. Therefore, it is probable that 40 percent of these 1100-hour limited-life parts with time already accrued on them were reinstalled in overhaul assemblies to go another 1100 hours. This would then exceed their retirement life.

Only 11 percent of the 204-012-104-5 strap pins were replaced during the first overhaul, and none were replaced during the second overhaul of the 204-012-101-3/-5 main rotor hubs. This means that some of these pins with more than 1100 hours on them have a probability of accumulating greater than 2200 hours. This would then exceed their retirement life. The same situation to a lesser degree exists for the 204-012-112-5 straps on the same assembly.

A similar situation exists for the 204-012-112-7 straps on the 540-011-101-5 and 540-011-101-9 assemblies.

Only 82 percent of the 540-011-452-5 support assemblies on the 540-011-450-7 swashplate were replaced at first overhaul. This means that 18 percent were reinstalled to begin another 1100-hour TBO interval after already accruing flight hours. When the assemblies went through the second overhaul, only 55 percent of the supports were replaced. This means that 45 percent of the supports will have accumulated time before they are installed to begin another 1100-hour TBO interval. Since the scheduled retirement interval on the support is 1100 hours, it is quite probable that this time will be exceeded on at least some of the supports, assuming at least part of the assemblies survive to their TBO.

Several of the parts in hubs and swashplates have retirement lives of 3300 hours. While the data are inadequate to evaluate a numerical probability of retirement life exceedance, a qualitative probability exists since there is no way in which their accumulated time is being tracked. Also, if 1100-hour retirement life assemblies can be reinstalled during overhaul so that they can exceed their retirement life, it is reasonable to assume that the 3300-hour parts will also be reinstalled to exceed their retirement lives.

3.3 ANALYSIS OF ACCIDENT DATA

The accident data analysis revealed that only a small percentage of the mishaps resulting in forced landings or damage to the aircraft, less than 6 percent, was concerned with material failures of the five drive system components. This is equivalent to a mishap rate of almost 1 per 100,000 flight hours.

Most of these mishaps, 97 percent, concerned the main transmission (50 percent), 90-degree gearbox (36 percent), and 42-degree gearbox (11 percent). Of the remaining 3 percent, 2 percent concerned the main rotor hub and 1 percent concerned the swashplate.

The percentage of the precautionary landing mishaps which was concerned with material failures of the five drive system components, 9.6 percent, was somewhat greater than the 6 percent observed for the more serious mishaps. The 9.6 percent is equivalent to a mishap rate of 1 per 37,700 flight hours.

As was the case for the more serious mishaps, 97 percent of the precautionary landing mishaps related to the main transmission (73 percent), 90-degree gearbox (19 percent), and 42-degree gearbox (4 percent). This group of mishaps does not include the chip detector warning system failures or fuzz warnings.

Table 30 shows how the mishaps were distributed among the five aircraft models.

The accident record narrative card data of the mishaps on the five types of drive system assemblies were reviewed to identify the assembly failure modes, wherever possible. The results of this review are shown in Tables 31 through 40. The failure mode descriptions for the forced landing and aircraft damage mishaps were compared with the failure mode descriptions of the precautionary landing mishaps in an effort to identify parts of the assemblies which should be included in the failure modes and effects analysis.

The parts identified were:

Main Transmission

- Input Quill - for loss of drive into transmission.

- Tail Rotor Output Quill - for loss of tail rotor drive.

- Lower Sun Gear - for failure.

- Planetary Gear - for failure.

- Lower Planetary Gear Bearing - for failure.

42-Degree Gearbox

- Input Spline Coupling - for loss of drive.

- Input Bevel Gear - for loss of drive.

90-Degree Gearbox

- Input spline coupling - for loss of drive.

- Output Gear - for loss of drive.

Main Rotor Hub

None

Swashplate (UH-1B/D/H)

- Trunnion - for failure resulting in loss of drive-to-scissors assembly.

3.4 FAILURE MODES AND EFFECTS ANALYSIS OF SELECTED PARTS OF THE DRIVE SYSTEM ASSEMBLIES

Parts thought to be potentially critical were selected for failure modes and effects analysis (FMEA). The results presented in Appendix B indicate that no part of any assembly has a failure mode that would impair flight safety that would not be preceded by degradation adequate to be observed either by the inspection processes or by the caution and warning systems.

Table 41 shows the ratios which resulted from the comparison of the percentage of the parts installed that were replaced from the assemblies removed for the more critically coded removal causes and the percentage of the parts that were replaced from the group of assemblies with records of sequential overhauls (data from Tables 18 through 28). The process followed to obtain the ratios was described in Section 2.5.3.

The FMEA (Appendix B) was performed on the parts listed in Table 41 and the parts also shown to be potentially critical by the accident data analysis. The conditions shown in Table 42 causing replacement of the parts were used as an input for the FMEA. The parts for which it was determined that the replacement percentage ratio shown on Table 41 was the result of an assembly modification rather than a degradation condition were deleted from the FMEA. Table 42 shows by percentage of total replacement causes the proportional distribution of the part conditions described by the disassembly inspection summary records.

The FMEA showed no part to have failure modes which would limit on-condition maintenance capability.

4.0 EVALUATION OF CURRENT ASSEMBLY CONDITION MONITORING PROCEDURES AND DEVICES

The condition of the entire UH-1/AH-1 drive system is monitored by maintenance personnel in conformance with instructions contained in the preventive maintenance inspection requirement cards and special inspection and test flight inspection requirements included in the organizational maintenance manual. The requirements for the AH-1G covering the five components in this study have been extracted from the technical manuals and are presented in Appendixes C, D, and E. These requirements are typical of those established for the UH-1 models.

While the current diagnostic and inspection procedures do not identify an internal problem of an assembly with a specific internal part, most of the significant modes of internal part degradation should be recognized by one of the warning systems or during inspection. The rest should cause excessive vibration during aircraft operation which would in turn require a troubleshooting check or component replacement. Failure modes of external parts of an assembly should be observed by inspection.

4.1 INSPECTION PROCEDURES

The current preventive maintenance inspection procedures for each of the five components being analyzed are as follows.

- Main Transmission -

Daily Inspection (Preventive Maintenance Daily (PMD)) - Check the transmission and connections for damage and oil leaks. Check sump for water contamination (if aircraft has been sitting for a long period) and for oil level. Check transmission oil filter for bypass indication and sight glass for damage.

Intermediate Inspection (Preventive Maintenance Intermediate (PMI)) - Perform everything per PMD, plus inspect and clean transmission oil screen and magnetic plug, and check continuity of system. Take oil sample per procedures in TB 556650-30-15 (Spectrometric Oil Analysis).

Periodic Inspection (Preventive Maintenance Periodic (PMP)) - Perform everything per PMI, plus replace external oil filter, change transmission oil, and clean pump screen.

- 42-Degree and 90-Degree Gearbox Assemblies -

PMD - Check for security, oil level and leaks. Inspect sight gage for damage or strain.

PMI - Perform everything per PMD, plus inspect and clean magnetic plug and check continuity of systems. Also inspect filler caps for clogged vent. On 90-degree gearbox only, inspect the mount casting for evidence of chafing by vertical fin door. Take oil sample from both gearboxes as per instructions outlined in TB 556650-300-15 (Spectrometric Oil Analysis).

PMP - Same as PMI, plus change the oil in both gearboxes.

- Main Rotor Hub -

PMD - Check main rotor pillow block and grip reservoir for oil level, leakage, and contamination.

PMI - Exactly the same as the PMD.

PMP - Same as the PMI, plus flushing the pillow block.

- Swashplate and Support -

PMD - Visually inspect control lugs on swashplate inner ring for cracks. Visual inspection is also required on swashplate with load transfer devices installed.

PMI - Same as PMD.

PMP - Same as PMI, plus check for excessive play in bearings and bushings between collective sleeve drive plate and mast.

Daily inspections of the drive system are absolutely necessary to assure continued safe operation. Daily inspections are limited to visual and touch examination of the components. The internal functions are not checked by a ground run-up for this maintenance event which could permit a critical failure mode of a dynamic interior part to go undetected. Yet the frequency of this inspection (to be performed after the last flight of the day or preceding the first flight the next day), coupled with the diagnostic monitoring and fault warning devices, compensates for its limitations. The daily inspection could be more effective if it were modified to include dynamic checks of the drive system to identify the presence of unusual noise or vibration.

The intermediate inspection is scheduled to be performed every 25 flight hours on the UH-1/AH-1 helicopters. It is, for the most part, an extension of the daily. For all components reviewed, the intermediate inspection includes all phases of the daily plus the inspection and cleaning of screens, magnetic plugs, and filler caps for the transmission and gearboxes. There is no difference between the daily and intermediate inspections for the main rotor hub and swashplate assemblies.

The PMI calls for taking oil samples from the transmission and gearboxes for spectrometric analysis. It is performed to detect those failures which are characterized by an abnormal increase in the wear metal content of the lubricating oil and advance at a rate slow enough to permit corrective action. Progressive fatigue damage cannot be detected by this technique. The inspection of screens and magnetic plugs does aid in detecting metallic particles or other material that may indicate oil contamination or internal failure. Also, during inspection of the magentic plugs, the chip detector system can be checked for proper functioning.

The periodic inspection covers all events outlined in the daily and intermediate inspections, plus changing oil and oil filters and checking for excessive play in bearings and bushings for all applicable components. Changing oil in the systems reduces the possibility of false chip detector indication due to fuzz accumulation resulting from normal wear, and also reduces the probability of oil contamination. The PMP, performed every 100 flight hours, provides a comprehensive, thorough, and searching inspection of those items which are subject to adjustment discrepancies or failure.

Due to specific conditions or incidents which randomly arise (such as hard landings, overspeed, sudden stoppage, etc.), special immediate inspections are required to further ensure safe flight. In the process of these inspections, major components within the power and drive systems, depending upon the type of incident and degree of damage, may be replaced and sent to overhaul for teardown analysis.

4.2 FAULT WARNING AND DIAGNOSTIC DEVICES

The fault warning and diagnostic devices located in the transmission consist of the following: (See Figure 11 for relative position of the devices within the transmission oil system numbered below.)

(1) Visual indication of the oil level in the transmission (checked on PMD) is provided by two small transparent plastic plugs set into the right side of the sump case, backed by indicator disc with FULL and LOW markings. Careful inspection must be made of the oil level sight gages to ensure that they are not oil stained internally, which would give erroneous indications of proper oil level.

(2) The transmission oil pump screen located in the sump (checked and cleaned on PMI) may indicate oil contamination or internal failure if metal particles are found upon cleaning.

(3) The transmission chip detector (checked and cleaned on PMI) is located next to the pump screen. When the magnetic pole attracts sufficient metal chips to complete the circuit between the pole and the ground, the CHIP DETECTOR segment on the caution panel will illuminate. The presence of metal particles, however, is not necessarily an indication that the transmission or gearbox is no longer serviceable. The quantity, source, form, and type of metal found, together with the service history of the particular component, must be taken into consideration. Time Since New (TSN) and Time Since Last Overhaul (TSLO), previous failures, and the type of operation are also important factors in determining the further serviceability of the unit. Chip detector illumination from either the transmission, the 42-degree gearbox, or 90-degree gearbox warrants an abort to the nearest safe landing area, which in most cases will be the home base. Upon landing, an inspection of the respective magnetic plug should be made and, depending upon the quantity and/or size of the metal particles, the proper maintenance action should be initiated.

(4) The transmission oil pressure indicator provides continual readings in psi by means of an electrical transmitter mounted directly into the oil manifold.

(5) The transmission oil pressure warning light provides an operational cross-check with the indicator. If the oil pressure in the transmission drops below 28 psi, the warning light should illuminate, indicating a defective relief valve or oil pump.

(6) The transmission oil temperature indicator continually measures the temperature in the oil manifold.

(7) The transmission oil temperature hot light provides an operational cross-check with its indicator. If the transmission oil temperature becomes greater than 230°F and the other affected systems are within the limits, then the transmission should be checked for internal failure. If excessive transmission oil temperature or low transmission oil pressure are indicated, then the pilot is instructed to proceed as follows:

- Accomplish a normal landing at the nearest safe landing area.

- Do not continue flight until the cause has been determined and corrective action taken.

The transmission has two filters; an internal sump filter and an external filter in the oil line from the oil coolers. Both filters have internal bypass valves which activate should the filter elements become clogged. Only the external filter has a signal when the bypass valve has been activated. However, nowhere in the organizational maintenance manuals are there any diagnostic instructions relating to the two filters. TM55-1520-210-PMS, UH-1D/H Aircraft Preventive Maintenance Services, dated 9 May 1975, which replaced the PMD, PMI and PMP documents dated 1969, give instructions for cleaning the internal sump filter every 25 hours and replacing the filter element and cleaning the housing of the external filter every 100 hours. It is possible that criteria could be established to permit the filter conditions to provide a diagnostic function. A study would be necessary to correlate the contaminant collected in the filter with the wear condition of the transmission before criteria and inspection procedures could be established.

The 42- and 90-degree gearboxes have some of the same diagnostic devices. Each contains an oil level sight gage for visual checks on the PMD and a magnetic chip detector (checked and cleaned on PMI) which illuminates only one warning light on the caution panel if sufficient particles are attracted to either gearbox. Unlike the transmission, a chip indication cannot be isolated to either one of the gearboxes until the magnetic plug is first removed and then retested. This system (used only on the UH-1 series) limits the effectiveness of the chip detectors in the gearboxes as an in-flight tool to pinpoint the troubled area. The AH-1G caution system allows complete isolation to either gearbox and transmission.

The fault warning devices located on the main rotor hub consist of four sight glasses for visually checking the oil level in the UH-1 (other than the 540 system) grip reservoirs and pillow blocks during the PMD. If a grip reservoir becomes empty during a two-hour flight or nonoperation for over 24 hours, then replacement of the grip seals is required.

There are no warning or diagnostic devices located on the swashplate.

5.0 CONCLUSIONS

5.1 RESULTS OF THE STUDY

There appears to be no doubt on the basis of the study that the five types of drive system components that have been installed on the UH-1 and AH-1 series aircraft have an on-condition maintenance capability. Their failure distributions approximate an exponential distribution within the scheduled operating intervals. The assemblies as operated, maintained, and monitored have fail-safe designs. Their scheduled TBO interval could be extended or eliminated and the current inspection procedures and diagnostic and warning system devices would be adequate to monitor the modes of degradation and to observe when the assembly condition is no longer acceptable. This would signal assembly replacement. Indeed, it can only be concluded that the drive system components are already depending on these condition-monitoring procedures as far as safe-operation dependence is concerned. The TBO interval for many assemblies is only an unneeded interruption in assembly operation which creates unnecessary cost.

With the more discernible capabilities of advanced diagnostic techniques supplementing the current transmission and gearbox monitoring devices, the necessary replacement may be scheduled to be done at a reasonably convenient time.

5.2 TEMPERING OBSERVATIONS

The above conclusions should be tempered with the following observations. Since both the main rotor hub and the swashplate have retirement schedules for some parts which make up the assembly, the on-condition maintenance capability of these assemblies should be limited to the retirement time on the life-limited parts.

It has been observed that the overhaul procedure followed for the drive system components studied loses completely any identification of accumulated time on the parts installed. This may be most serious for the rotor hub and swashplate parts which have retirement schedules.

The main reason that the on-condition maintenance capability exists is that the fatigue life on the dynamic parts is considered to be unlimited. Certainly the fatigue life is long enough that the wear mode of degradation will proceed to an unacceptable condition long before a fatigue failure would occur. But this is true because these UH-1/AH-1 assembly parts were designed to have this fail-safe characteristic within the limits of the operating loads expected. However, as design modifications are introduced to permit the aircraft to carry greater loads higher and faster, care must be taken to maintain this fail-safe characteristic. With increased engine power available and under conditions of mission stress, loads in excess of those for which these parts were designed may be more frequently applied. This could cause part fatigue failures to occur before the wear mode becomes significant. This suggests that aircraft with high power capability should have overtorque monitor recorders. It also suggests areas for further study that are included in the next section.

6.0 RECOMMENDATIONS

6.1 LOAD LEVEL STUDY TO DETERMINE LIMITS OF FAIL-SAFE DESIGN CHARACTERISTICS

Since on-condition maintenance capability depends on a fail-safe design (a design in which the assembly will display an unacceptable level of degradation long before it would experience a failure mode which would cause it to cease functioning), it is important to know how the dynamic parts of these assemblies react to increased load levels. It is recommended that further study be done and testing be performed on drive system assembly dynamic parts to answer three questions:

- How does the rate of wear degradation change with increasing load levels?

- How does the fatigue life of these parts change with increasing load levels?

- At what load level, if any, will fatigue failure occur before the wear degradation becomes unacceptable?

6.2 STUDY TO DETERMINE SUPPORT REQUIREMENTS FOR A FLEET OF AIRCRAFT WITH DYNAMIC COMPONENT OVERHAUL PERFORMED ON CONDITION

The planning and scheduling of spare assemblies and replacement parts for dynamic components overhauled on condition and without a scheduled TBO has been expressed as a difficult logistics problem. A study should be made, supported by a simulation model to establish guidelines, and perhaps a procedure to plan and schedule for on-condition capability.

6.3 STUDY TO DETERMINE THE IMPACT OF HAVING LIFE-LIMITED PARTS OPERATING IN THE SYSTEM BEYOND THEIR SPECIFIED RETIREMENT LIFE

The procedure used to rebuild assemblies during overhaul (where parts removed, inspected and found acceptable after component disassembly are commonly stored and indiscriminately selected) was discussed in Section 2.1.3. The recommendation stated there is repeated here.

It is recommended that a study be conducted to determine whether the probability of having life-limited parts of the main rotor hub and swashplate operating beyond their specified retirement life is serious. If it is found to be serious, then it is further recommended that a solution be worked out before operational safety of the aircraft is impaired.

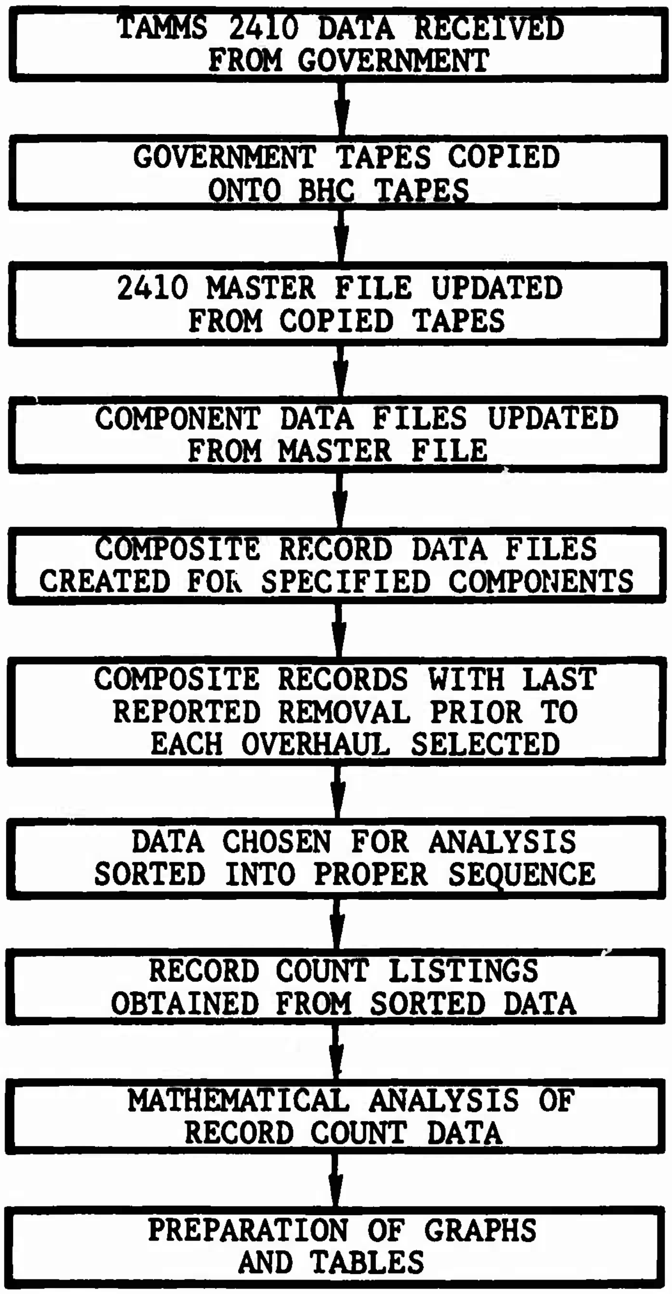

Figure 1. Component removal records analysis flow process.

SEQUENTIAL OVERHAUL LIST

Assembly: ______________________________

O/H No.	Initial S/N / Subsequent S/N	Part Number	Time Since New at Removal	Time Since Overhaul at Removal	Removal Cause	Data Source	
						Comp. List.	Forms
						(Analyst can note source of a particular overhaul, for ease of traceability for future reference).	

Figure 2. Sequential component overhaul listing form.

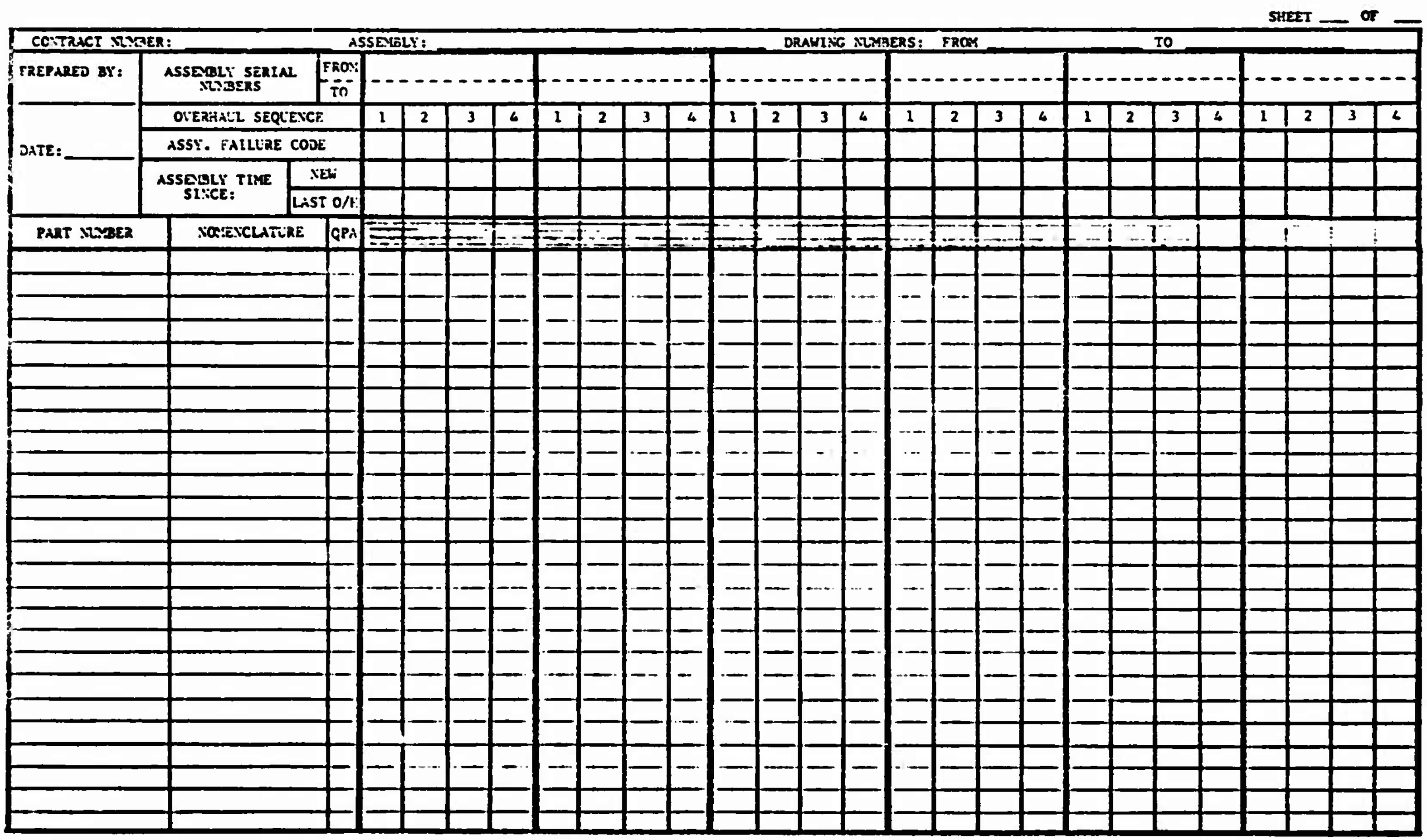

Figure 3. Form for recording number of parts replaced per overhaul by component serial number.

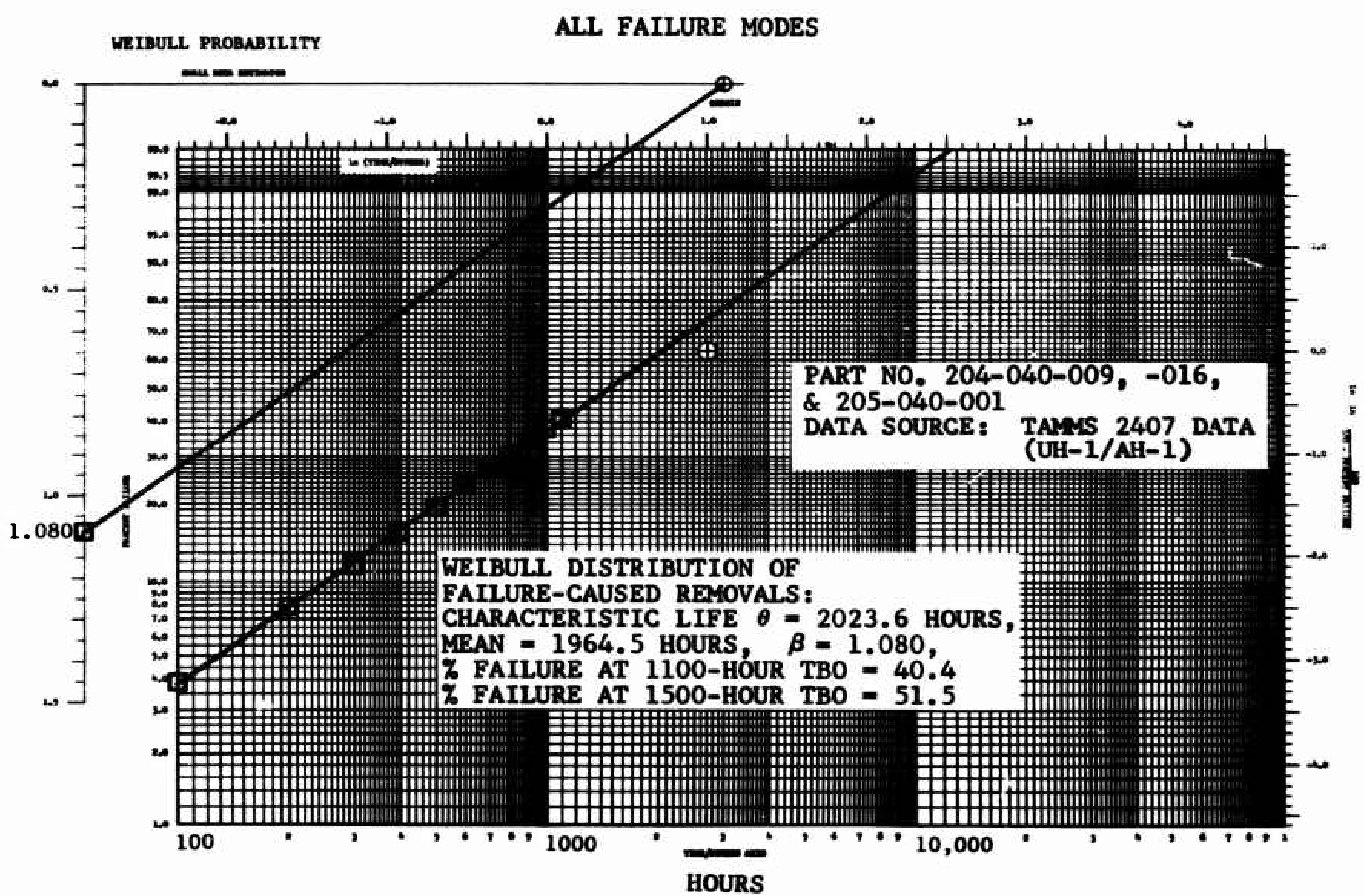

Figure 4. Weibull distribution of main transmission failure caused removals.

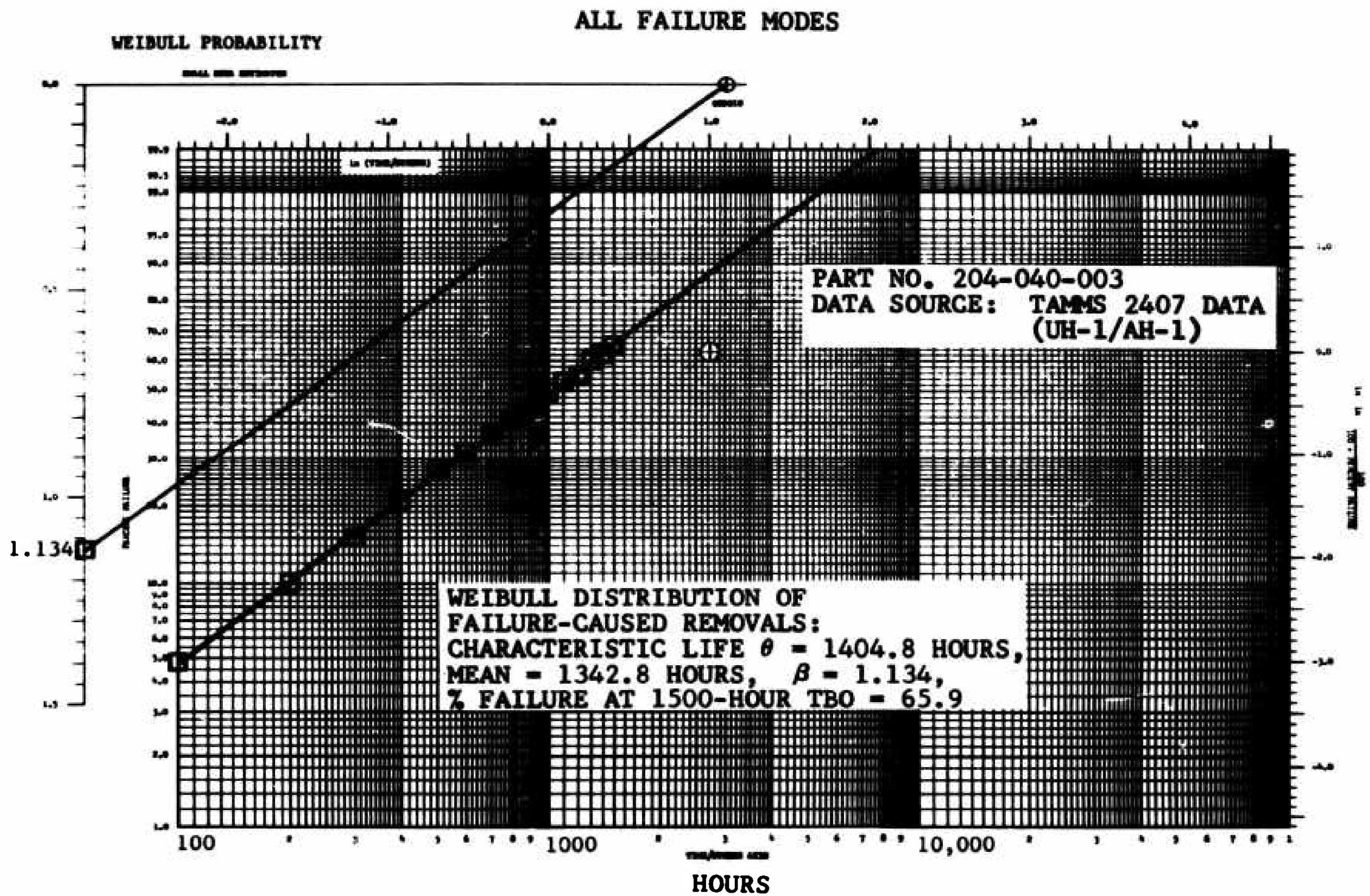

Figure 5. Weibull distribution of 42-degree gearbox failure caused removals.

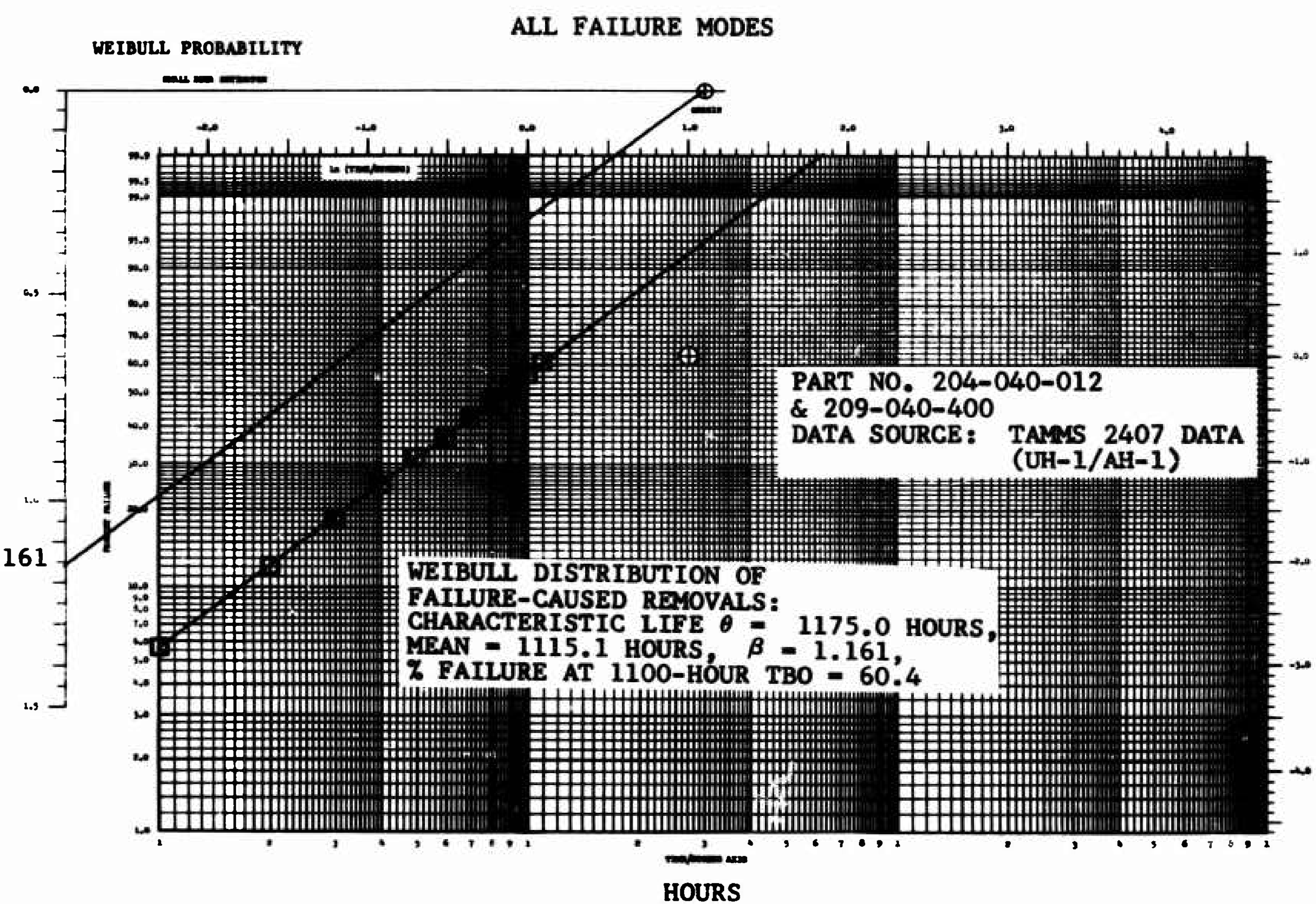

Figure 6. Weibull distribution of 90-degree gearbox failure caused removals.

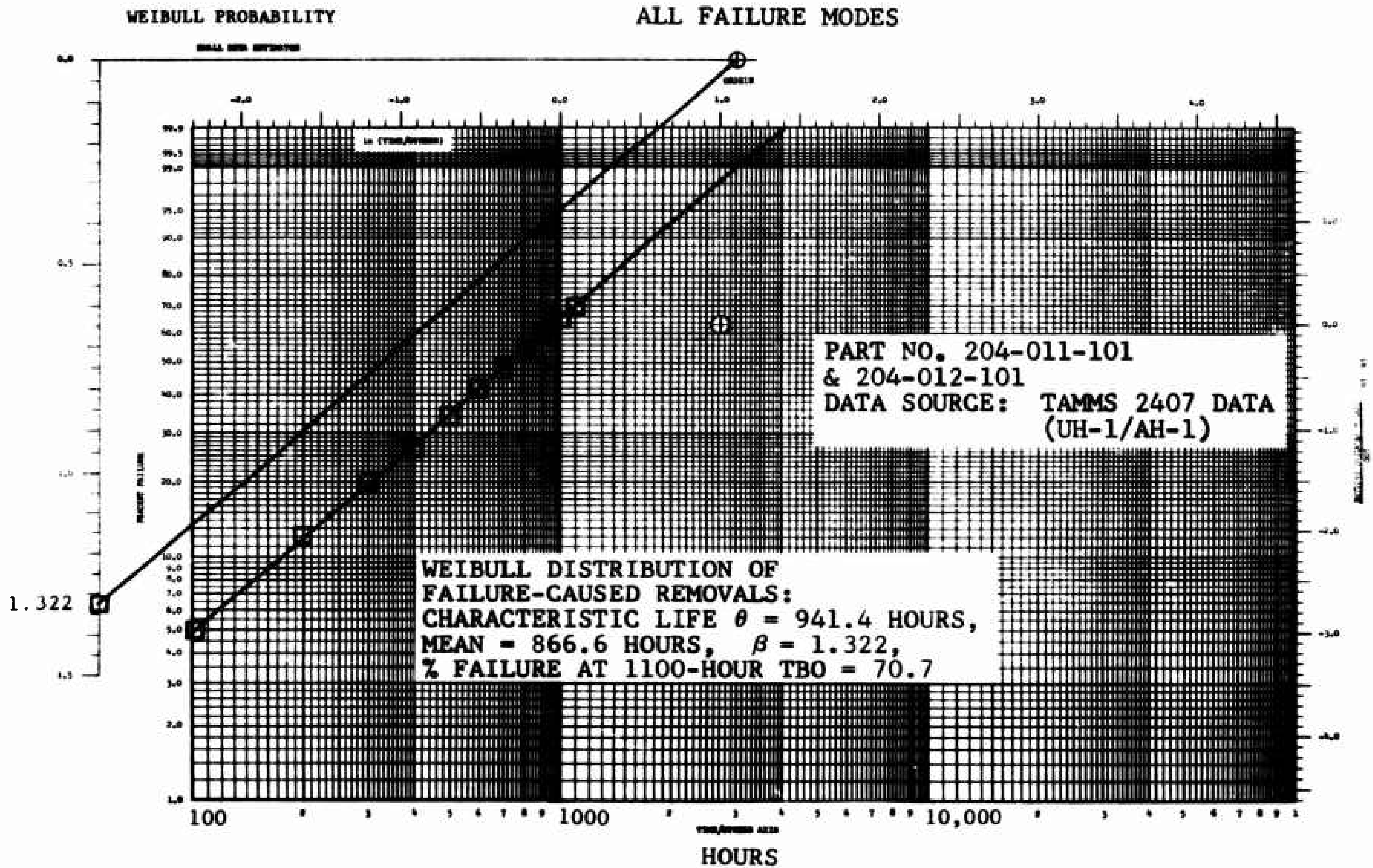

Figure 7. Weibull distribution of UH-1B/D/H type main rotor hub failure caused removals.

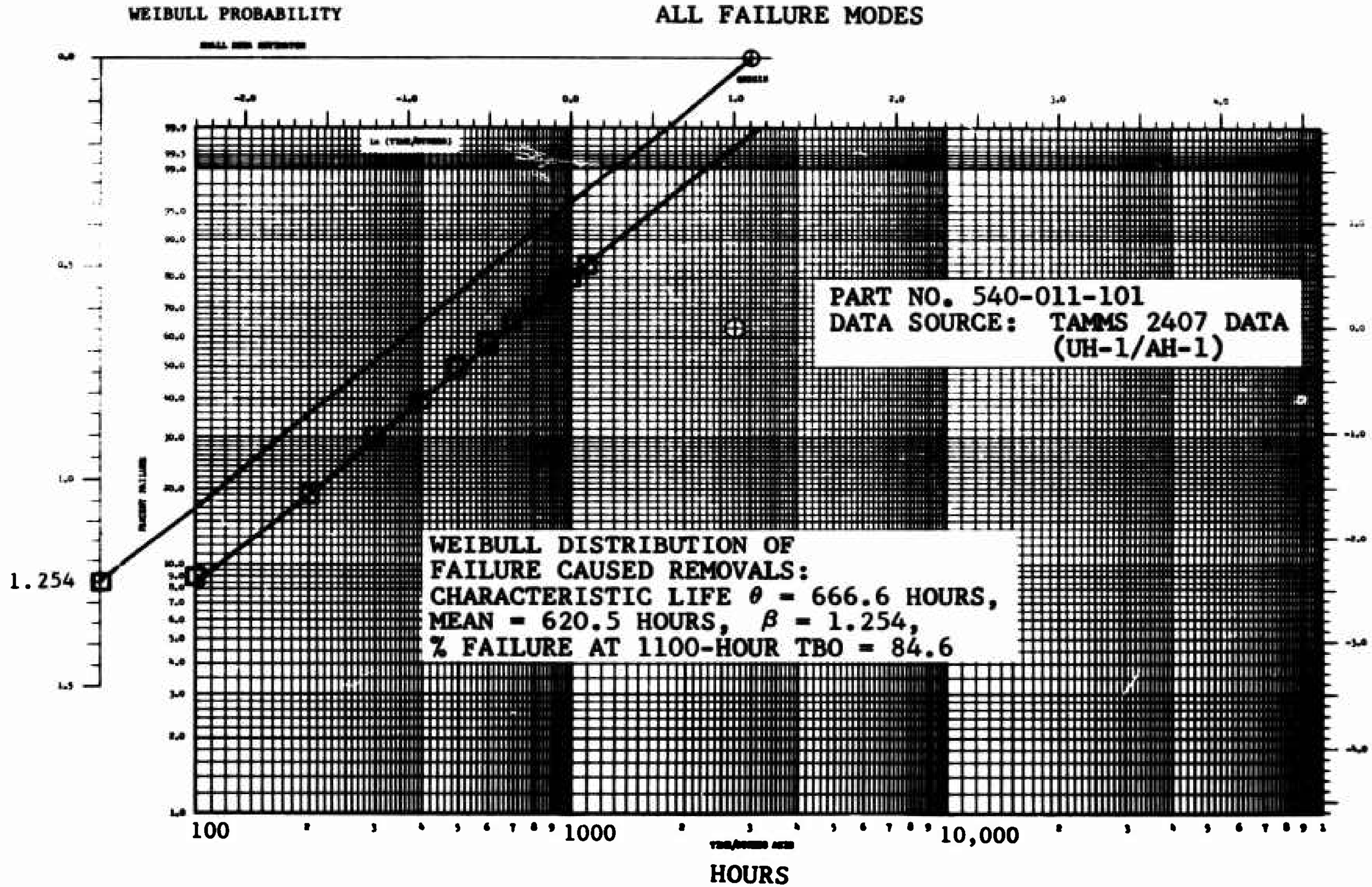

Figure 8. Weibull distribution of UH-1C/AH-1G type main rotor hub failure caused removals.

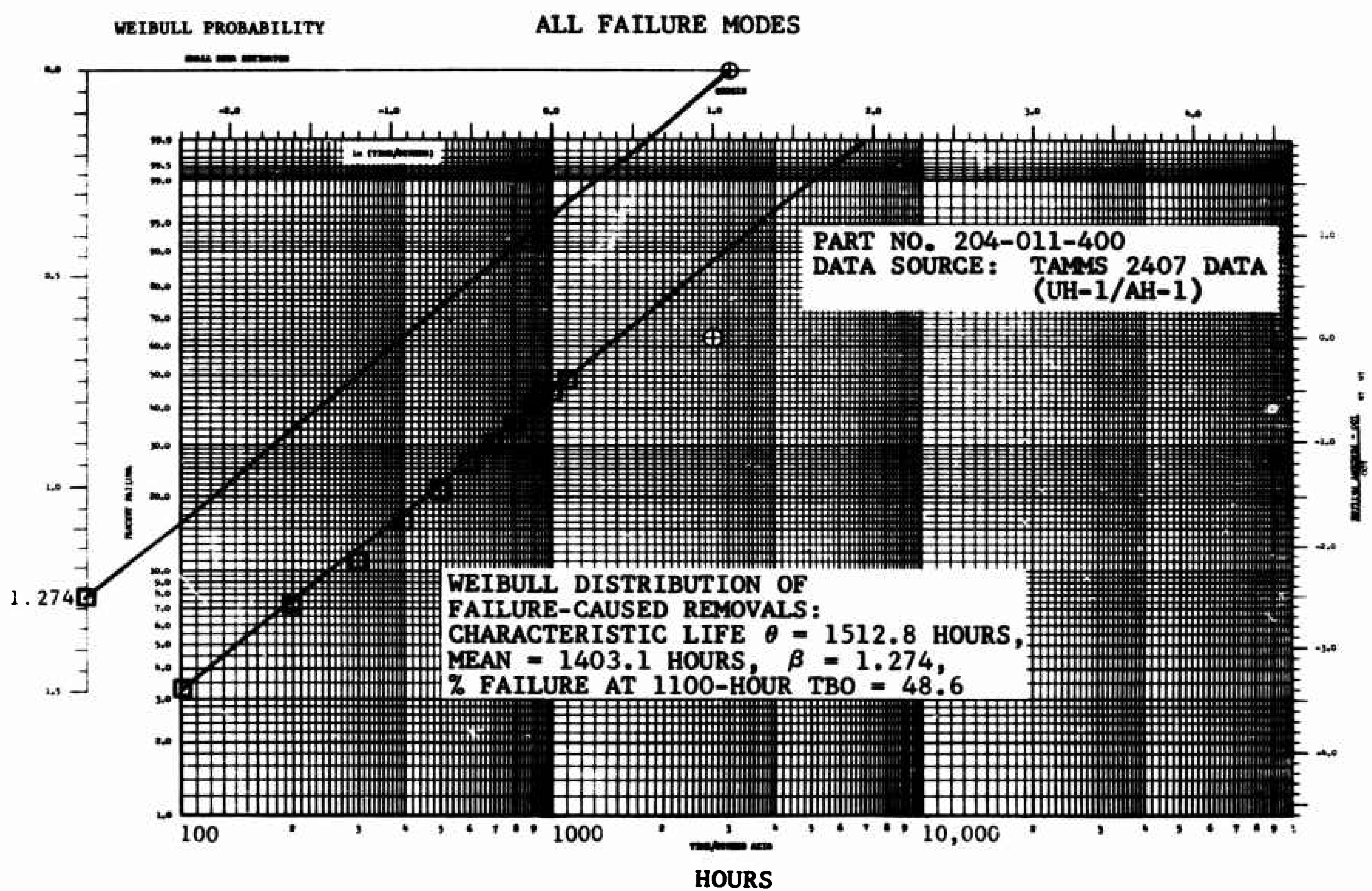

Figure 9. Weibull distribution of UH-1B/D/H type swashplate failure caused removals.

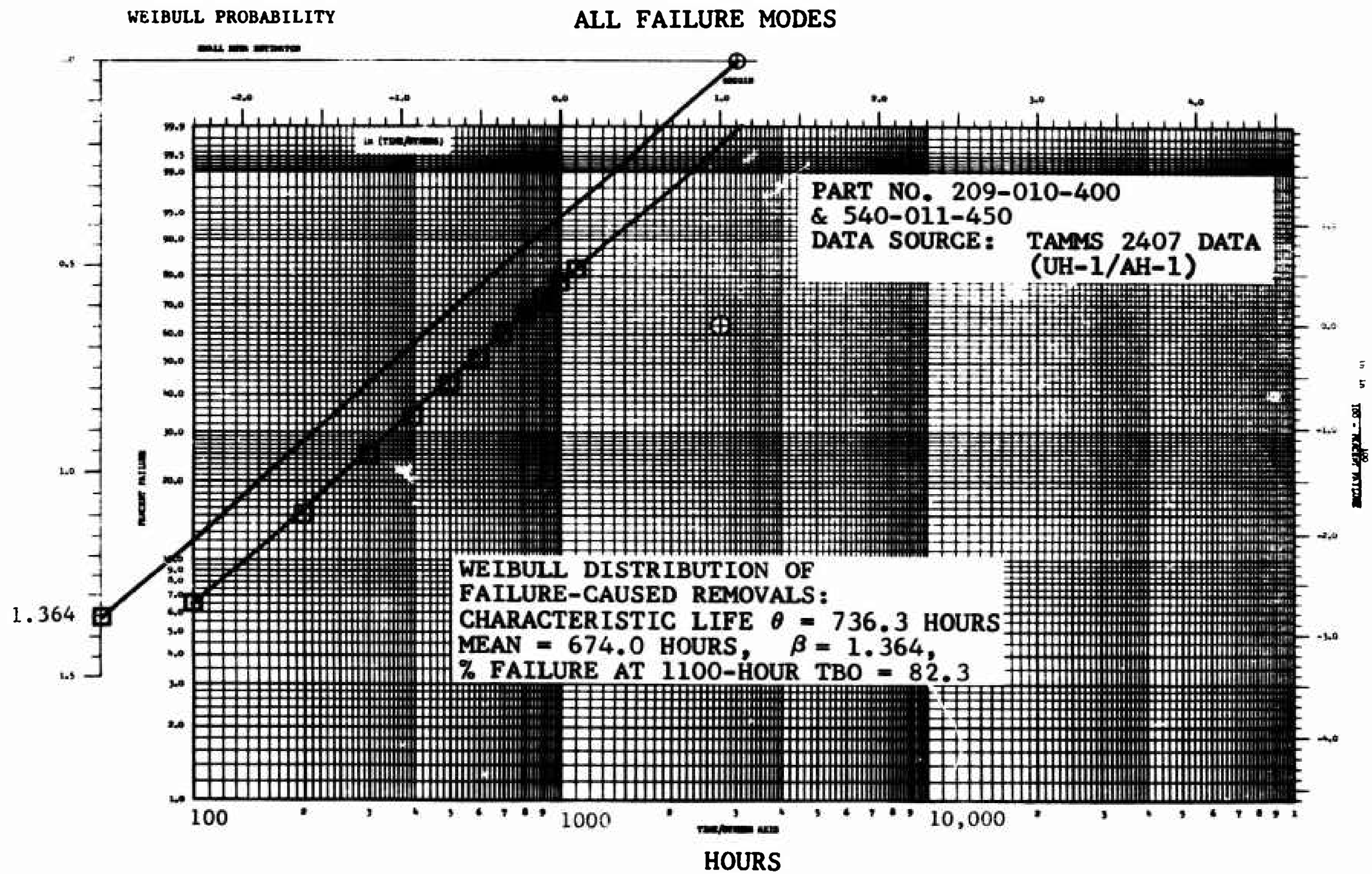

Figure 10. Weibull distribution of UH-1C/AH-1G type swashplate failure caused removals.

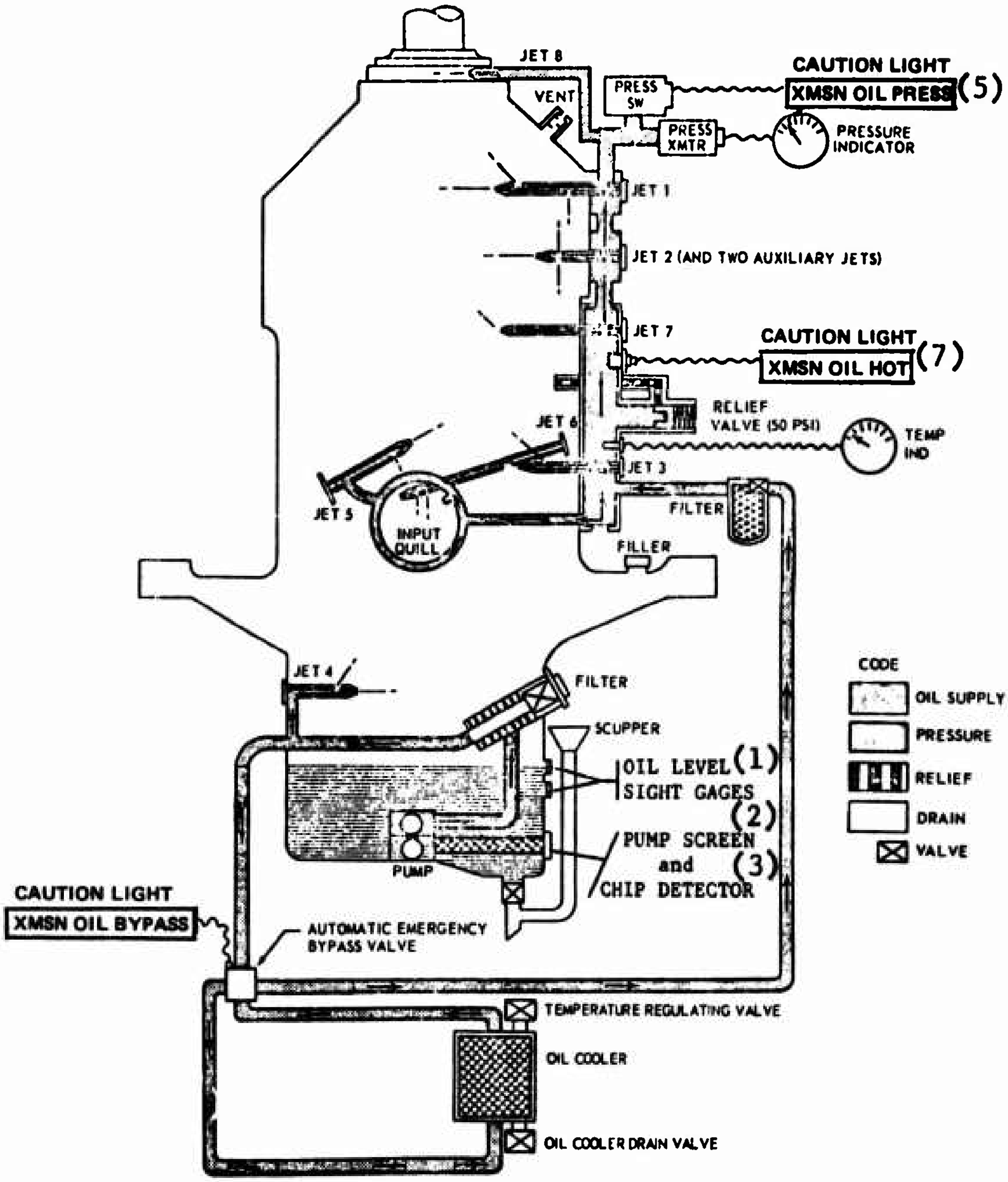

Figure 11. Schematic of the transmission oil system.

TABLE 1. THE DRIVE SYSTEM COMPONENTS AND THEIR EFFECTIVITY

ASSEMBLY Model	Part Number	FIIN*	Effectivity Statement in TM55-1520-210-34P Or TM55-1520-221-34P Tech Manuals
SWASHPLATE			
UH-1B/D/H	204-011-400-1	787-2502	Repl by -7
	204-011-400-3	873-2231	Repl by -7
	204-011-400-5	856-3917	Repl by -7
	204-011-400-7	472-7310	Obs-Aft-Cmpl-W MWO 55-1500-200-20/4
	204-011-400-9	930-0083	Obs-Aft-Cmpl-W MWO 55-1500-200-30/2
	204-011-400-11	060-1062	Use-Aft-Cmpl-W MWO 55-1500-200-30/2
UH-1C/M	540-011-450-3	921-6162	Obs-Aft-Cmpl-W MWO 55-1520-211-30-16
	540-011-450-5	930-6108	Repl by -7
	540-011-450-7	911-9292	
AH-1G	209-010-400-1	914-6160	Use
M/R HUB			
UH-1B	204-011-101-1	787-2510	Repl by -11
	204-011-101-3	876-0106	Repl by -11
	204-011-101-5	085-3888	Repl by -11
	204-011-101-9	991-8904	Repl by -11
	204-011-101-11	886-1778	Use
UH-1C	540-011-101-1	847-7462	Not listed in current manuals
UH-1C/M	540-011-101-3	921-6821	Obs-Aft-Cmpl-W MWO 55-1520-211-30/18
	540-011-101-7	930-8352	Obs-Aft-Cmpl-W MWO 55-1520-211-30/23
	540-011-101-9	933-6823	Use-Aft-Cmpl-W MWO 55-1520-211-30/18 & 30/23
UH-1D/H	204-012-101-3	788-5321	Repl by -19
	204-012-101-5	833-1556	Repl by -19, Rework to -19 (1615-213-7261)
AH-1G	540-011-101-5	918-9357	Repl by -17 (1615-033-6313) Obs-Aft-Compl-W MWO 55-1520-221-30/42
TRANSMISSION			
UH-1B	204-040-009-7	733-8309	Repl by -61
	204-040-009-13	856-3862	Repl by -61
	204-040-009-19	970-1258	Repl by -61
	204-040-009-31	056-4868	Repl by -61
	204-040-009-61	919-1352	
UH-1C/M	204-040-009-53	871-8735	Repl by -57
	204-040-009-57	919-1353	Use

TABLE 1. - Concluded

ASSEMBLY Model	Part Number	FIIN*	Effectivity Statement in TM55-1520-210-34P Or TM55-1520-221-34P Tech Manuals
TRANSMISSION (Cont'd)			
UH-1D/H	205-040-001-5	969-9187	Repl by -17
	205-040-001-11	070-6838	Repl by -17
	205-040-001-17	919-1351	Use
AH-1G	204-040-009-65	929-5807	Use
UH-1B/C/D/H/M/, AH-1G	204-040-016-1	089-6509	Repl by -5
	204-040-016-3	813-9225	Repl by -5
	204-040-016-5	183-0834	Used on 009-57, 61 & 65, & 000-17
42° GEARBOX			
UH-1B/C/M	204-040-003-13	633-0864	Repl by -37
UH-1B/C/D/H/M	204-040-003-23	776-1626	Repl by -37
	204-040-003-29	472-7306	Repl by -37
UH-1B/C/D/H/M, AH-1G	204-040-003-37	918-2676	Use
90° GEARBOX			
UH-1B/C/D/H/M	204-040-012-1	961-4426	Repl by -13
	204-040-012-7	472-7305	Repl by -13
UH-1B/C/D/H/M, AH-1G	204-040-012-13	918-2677	Usbl AH-1G 66-15249 thru 69-16447 Obs-Aft-Cmpl-W MWO 55-1520-221-40/3
AH-1G	209-040-400-11	490-5877	Usbl AH-1G 70-15936 and Sub

* FIIN - Federal Item Identification number, the last seven numbers of the Federal stock number.

TABLE 2. AIRCRAFT TECHNICAL MANUALS USED DURING THE STUDY

	TM55-1520-XXX-XX Manual Numbers and Publication Dates*			
	Model UH-1B	Model UH-1C	Model UH-1D/H	Model AH-1G
Organizational Maintenance Manual	-219-20 Jan. 1969	-220-20 Nov. 1968	-210-20 May 1969	-221-20 Sept. 1971
Preventive Maintenance Daily Inspection Checklist	-219-PMD July 1970	-220-PMD Nov. 1968	-210-PMD Nov. 1969	-221-PMD Jan. 1970
Preventive Maintenance Intermediate Inspection Checklist	-219-PMI July 1970	-220-PMI July 1968	-210-PMI Nov. 1969	-221-PMI Jan. 1970
Preventive Maintenance Periodic Inspection Checklist	-219-PMP July 1970	-220-PMP April 1973	-210-PMP Nov. 1969	-221-PMD Jan. 1970
DS and GS Maintenance Repair Parts and Special Tool List	-210-34P April 1974	-210-34P April 1974	-210-34P April 1974	-221-34P Aug. 1974

* Published by Headquarters, Department of the Army, Washington, D. C.

TABLE 3. DRIVE SYSTEM COMPONENT DA2410 RECORDS AVAILABLE FOR ANALYSIS

ASSEMBLY Model	Part Number	FIIN*	Total No. Records	Copy 1	Copy 3	Copy 4	Copy 5	Copy 6
SWASHPLATE								
UH-1B/D/H	204-011-400-1	787-2502	224	103	9	1	27	84
	204-011-400-3	873-2231	69	17	0	0	8	44
	204-011-400-5	856-3917	149	56	2	1	8	82
	204-011-400-7	472-7310	4,617	1,569	141	13	906	1,988
	204-011-400-9	930-0083	14,241	3,878	191	13	4,720	5,439
	204-011-400-11	060-1062	32,965	8,323	1,117	27	12,204	11,294
UH-1C/M	540-011-450-3	921-6162	643	259	9	0	198	177
	540-011-450-5	930-6108	1,380	144	3	1	661	571
	540-011-450-7	911-9292	4,446	1,222	77	15	1,782	1,350
AH-1G	209-010-400-1	914-6160	8,551	2,241	301	19	3,100	2,890
M/R HUB								
UH-1B	204-011-101-1	787-2510	78	45	3	0	7	23
	204-011-101-3	876-0106	365	166	23	4	42	130
	204-011-101-5	085-3888	385	135	40	2	65	143
	204-011-101-9	991-8904	7,474	2,606	486	42	1,791	2,549
	204-011-101-11	886-1778	4,554	1,290	245	1	1,692	1,326
UH-1C	540-011-101-1	847-7462	12	5	0	0	2	5
UH-1C/M	540-011-101-3	921-6821	1,278	383	26	1	307	561
	540-011-101-7	930-8352	793	83	1	0	316	393
	540-011-101-9	933-6823	8,385	2,824	162	12	2,691	2,696
UH-1D/H	204-012-101-3	788-5321	22,046	6,967	309	46	6,571	8,153
	204-012-101-5	833-1556	37,997	10,889	1,617	39	12,559	12,893
AH-1G	540-011-101-5	918-9357	13,748	4,643	341	21	3,783	4,996
TRANSMISSION								
UH-1B	204-040-009-7	733-8309	125	47	8	2	9	59
	204-040-009-13	856-3862	206	77	23	0	12	94
	204-040-009-19	970-1258	428	132	36	0	35	225
	204-040-009-31	056-4868	4,071	1,246	256	5	1,044	1,520
	204-040-009-61	919-1352	347	134	7	0	74	132
UH-1C/M	204-040-009-53	871-8735	499	190	14	0	116	179
	204-040-009-57	919-1353	3,313	780	24	3	1,125	1,381
UH-1D/H	205-040-001-5	969-9157	60	28	0	0	8	24
	205-040-001-11	070-6638	2,333	868	63	6	516	880
	205-040-001-17	919-1351	12,578	2,853	162	2	4,325	5,236

TABLE 3. - Concluded

ASSEMBLY Model	Part Number	FIIN*	Total No. Records	Copy 1	Copy 3	Copy 4	Copy 5	Copy 6
TRANSMISSION (Cont'd)								
AH-1G	204-040-009-65	929-5807	1,602	276	7	0	611	708
UH-1B/C/D/H/M/, AH-1G	204-040-016-1	089-6509	22,436	6,391	792	16	7,483	7,754
	204-040-016-3	813-9225	4,174	1,319	135	4	1,610	1,106
	204-040-016-5	183-0834	8,028	2,253	119	7	2,908	2,741
42° GEARBOX								
UH-1B/C/M	204-040-003-13	633-0864	158	83	3	0	24	48
UH-1B/C/D/H/M	204-040-003-23	776-1626	4,345	1,567	174	11	571	2,022
	204-040-003-29	472-7306	87	45	1	0	11	30
UH-1B/C/D/H/M, AH-1G	204-040-003-37	918-2676	59,800	15,634	2,444	55	22,067	19,600
90° GEARBOX								
UH-1B/C/D/H/M	204-040-012-1	961-4426	150	72	7	0	17	54
	204-040-012-7	472-7305	3,774	1,364	170	16	477	1,747
UH-1B/C/D/H/M, AH-1G	204-040-012-13	918-2677	67,542	18,617	3,084	75	23,654	22,112
AH-1G	209-040-400-11	490-5877	3,108	640	81	4	1,316	1,067

* FIIN - Federal Item Identification number, the last seven numbers of the Federal stock number.

TABLE 4. MAIN TRANSMISSION FAILURE MODE GROUPS OF FAILURE CODES

FAIL CODE	DESCRIPTION OF FAIL CODE	NO. OF RECS.	COMBINED FAILURE CODES									
			306	374	381	070	020	170	705	105	481	977
008	NOISY	45					X					
020	WORN EXCESSIVELY	130					X					
027	COLLAPSED	3				X						
031	ALIGNMENT IMPROPER	10							X			
040	MECHANICAL BINDING	1		X								
070	BROKEN	175				X						
105	LOOSE BOLTS, NUTS, SCREWS	11								X		
117	DETERIORATED	1					X					
127	ADJUSTMENT IMPROPER	2							X			
150	CHATTERING	2					X					
170	CORRODED	107						X				
171	BURRED	4					X					
190	CRACKED	85				X						
230	DIRTY	263	X									
233	ERRATIC	1										X
306	CONTAMINATION	156	X									
307	OIL LEAK	20			X							
308	OIL CONTAMINATION	17	X									
330	EXCESSIVE HUM	4					X					
370	JAMMED	5		X								
372	METAL ON MAGNETIC PLUG	224	X									
374	INTERNAL FAILURE	233		X								
381	LEAKING	233			X							
481	OVERHEATS	4									X	
523	PRESSURE TOO HIGH	2	X									
690	VIBRATION EXCESSIVE	17					X					
705	BEYOND SPECIFIED TOLERANCE	1							X			
840	SEIZED	9		X								
916	IMPENDING OR INCIPIENT FAIL. IND. BY SPECTRO. OIL ANALYSIS	72	X									
977	PRESSURE ERRATIC	1										X
TOTAL		1838	734	248	253	263	203	107	13	11	4	2

TABLE 5. 42-DEGREE GEARBOX FAILURE MODE GROUPS OF FAILURE CODES

FAIL CODE	DESCRIPTION OF FAIL CODE	NO. OF RECS.	COMBINED FAILURE CODES 381	020	306	070	374	481	170	705	105
008	NOISY	39		X							
020	WORN EXCESSIVELY	455		X							
027	COLLAPSED	12				X					
040	MECHANICAL BINDING	5					X				
070	BROKEN	127				X					
080	BURNED OUT	1						X			
104	BACKLASH HIGH	1		X							
105	LOOSE BOLTS, NUTS, SCREWS	2									X
117	DETERIORATED	5		X							
135	BINDING	2					X				
150	CHATTERING	2		X							
170	CORRODED	15							X		
171	BURRED	5		X							
185	CONTAMINATED WITH METAL	3			X						
190	CRACKED	51				X					
230	DIRTY	55			X						
231	ELONGATED	1		X							
240	FLAKING	1		X							
290	GROOVED	2		X							
306	CONTAMINATION	55			X						
307	OIL LEAK	62	X								
308	OIL CONTAMINATION	4			X						
330	EXCESSIVE HUM	4		X							
351	HIGH FREQUENCY VIBRATION	1		X							
370	JAMMED	4					X				
372	METAL ON MAGNETIC PLUG	88			X						
374	INTERNAL FAILURE	143					X				
381	LEAKING	2081	X								
473	SEAL BLOWN	3	X								
481	OVERHEATS	25						X			
501	GREASE LEAKAGE	1	X								
520	PITTED	3		X							
582	SEAL LEAKING	1	X								
640	SLIPPAGE	1		X							
690	VIBRATION EXCESSIVE	32		X							
701	WARPED	3								X	
705	BEYOND SPECIFIED TOLERANCE	2								X	
710	BEARING FAILURE	20		X							
730	LOOSE	9		X							
790	OUT OF ADJUSTMENT	3								X	
840	SEIZED	5					X				
910	CHIPPED	57		X							
916	IMPENDING OR INCIPIENT FAIL. IND. BY SPECTRO. OIL ANALYSIS	51			X						
935	SCORED	11		X							
TOTAL		3453	2148	649	256	190	159	26	15	8	2

TABLE 6. 90-DEGREE GEARBOX FAILURE MODE GROUPS OF FAILURE CODES

FAIL CODE	DESCRIPTION OF FAIL CODE	NO. OF RECS.	COMBINED FAILURE CODES								
			381	306	020	374	070	170	105	705	481
008	NOISY	18			X						
020	WORN EXCESSIVELY	560			X						
027	COLLAPSED	11					X				
040	MECHANICAL BINDING	4				X					
070	BROKEN	164					X				
080	BURNED OUT	1									X
104	BACKLASH HIGH	1			X						
105	LOOSE BOLTS, NUTS, SCREWS	9							X		
111	BURST	5					X				
114	CONTROLS, INOPERATIVE	1				X					
117	DETERIORATED	5			X						
135	BINDING	3				X					
150	CHATTERING	2			X						
170	CORRODED	20						X			
171	BURRED	5			X						
190	CRACKED	37					X				
214	FAILS DIAGNOSTIC	2		X							
226	EXCESSIVE PLAY	1			X						
230	DIRTY	154		X							
290	GROOVED	6			X						
306	CONTAMINATION	115		X							
307	OIL LEAK	54	X								
308	OIL CONTAMINATION	8		X							
330	EXCESSIVE HUM	1			X						
351	HIGH FREQUENCY VIBRATION	10			X						
370	JAMMED	5				X					
372	METAL ON MAGNETIC PLUG	333		X							
374	INTERNAL FAILURE	227				X					
381	LEAKING	2027	X								
425	NICKED	5			X						
473	SEAL BLOWN	1	X								
481	OVERHEATS	5									X
520	PITTED	3			X						
581	SEAL BROKEN	1	X								
690	VIBRATION EXCESSIVE	32			X						
701	WARPED	1								X	
705	BEYOND SPECIFIED TOLERANCE	4								X	
710	BEARING FAILURE	17			X						
730	LOOSE	11			X						
790	OUT OF ADJUSTMENT	6								X	
840	SEIZED	4				X					
910	CHIPPED	159			X						
916	IMPENDING OR INCIPIENT FAIL. IND. BY SPECTRO. OIL ANALYSIS	247		X							
935	SCORED	11			X						
	TOTAL	4296	2083	859	847	244	[illegible]	20	9	11	6

TABLE 7. MAIN ROTOR HUB FAILURE MODE GROUPS OF FAILURE CODES

FAIL CODE	DESCRIPTION OF FAIL CODE	NO. OF RECS.	COMBINED FAILURE CODES										
			020	381	070	374	705	670	306	170	561	780	105
008	NOISY	5	X										
020	WORN EXCESSIVELY	1182	X										
027	COLLAPSED	61			X								
031	ALIGNMENT IMPROPER	42					X						
040	MECHANICAL BINDING	17				X							
060	BRITTLE	3				X							
061	FUSED	1				X							
070	BROKEN	133			X								
105	LOOSE BOLTS, NUTS, SCREWS	7											X
111	BURST	13			X								
117	DETERIORATED	5	X										
127	ADJUSTMENT IMPROPER	75					X						
135	BINDING	19				X							
150	CHATTERING	1	X										
170	CORRODED	37								X			
171	BURRED	8	X										
190	CRACKED	121			X								
214	FAILS DIAGNOSTIC	10				X							
226	EXCESSIVE PLAY	1	X										
230	DIRTY	15							X				
231	ELONGATED	1	X										
233	ERRATIC	2						X					
240	FLAKING	1	X										
271	SPRUNG	10										X	
283	LEAKS OIL	2		X									
290	GROOVED	40	X										
306	CONTAMINATION	28							X				
307	OIL LEAK	115		X									
312	LEAKED (NOT ELECTRICALLY)	1		X									
370	JAMMED	15				X							
374	INTERNAL FAILURE	233				X							
381	LEAKING	2986		X									
473	SEAL BLOWN	3		X									
520	PITTED	18	X										
561	UNABLE TO ADJUST LIMITS	34									X		
640	SLIPPAGE	16	X										
670	UNBALANCED	34						X					
680	UNSTABLE	13						X					
686	IMPROPER TRACKING	4									X		
701	WARPED	18										X	
705	BEYOND SPECIFIED TOLERANCE	9					X						
710	BEARING FAILURE	471	X										
730	LOOSE	99	X										
780	BENT	8										X	
790	OUT OF ADJUSTMENT	32					X						
840	SEIZED	35				X							
910	CHIPPED	162	X										
935	SCORED	95	X										
TOTAL		6241	2105	3107	328	333	158	49	43	37	38	36	7

TABLE 8. SWASHPLATE FAILURE MODE GROUPS OF FAILURE CODES

FAIL CODE	DESCRIPTION OF FAIL CODE	NO. OF RECS.	COMBINED FAILURE CODES										
			020	070	381	855	374	135	170	670	780	306	105
008	NOISY	5	X										
020	WORN EXCESSIVELY	2075	X										
027	COLLAPSED	24		X									
040	MECHANICAL BINDING	9						X					
060	BRITTLE	4	X										
070	BROKEN	165		X									
105	LOOSE BOLTS, NUTS, SCREWS	7											X
117	DETERIORATED	5	X										
135	BINDING	1						X					
170	CORRODED	21							X				
171	BURRED	14	X										
190	CRACKED	113		X									
214	FAILS DIAGNOSTIC	5					X						
226	EXCESSIVE PLAY	1	X										
230	DIRTY	6										X	
232	END PLAY EXCESSIVE	1	X										
240	FLAKING	1	X										
271	SPRUNG	2									X		
290	GROOVED	62	X										
306	CONTAMINATION	15										X	
374	INTERNAL FAILURE	58					X						
381	LEAKING	71			X								
481	OVERHEATS	8				X							
520	PITTED	5	X										
561	UNABLE TO ADJUST LIMITS	8	X										
690	VIBRATION EXCESSIVE	9								X			
701	WARPED	2									X		
705	BEYOND SPECIFIED TOLERANCE	15	X										
710	BEARING FAILURE	439	X										
730	LOOSE	94	X										
780	BENT	9									X		
840	SEIZED	5						X					
855	HEAT DAMAGE	4				X							
900	BURNED	52				X							
910	CHIPPED	206	X										
935	SCORED	78	X										
TOTAL		3599	3013	302	71	64	63	15	21	9	13	21	7

TABLE 9. MAIN TRANSMISSION REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 204-040-009-11, -13, -23, -35, -53, -57, -61, -65
204-040-016-1, -3, -5
205-040-001-5, -11, -17

Reason for Removal	Number of Assemblies				% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)				17,794		
I. INHERENT FAILURE CAUSES (10.3%)			1,828		100.0	45.2
A. Contamination		734			40.2	18.1
Dirty	263					
Metal on Magnetic Plug	224					
Contamination	156					
Impending or Incipient Failure Indicated by Spectrometic Oil Analysis	72					
Oil Contamination	17					
Pressure Too High	2					
B. Internal Failure		248			13.6	6.1
Internal Failure	233					
Seized	9					
Jammed	5					
Mechanical Binding	1					
C. Leaking		253			13.8	6.3
Leaking	233					
Oil Leak	20					

TABLE 9. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
D. **Broken**		263	14.4	6.5
Broken	175			
Cracked	85			
Collapsed	3			
E. **Worn Excessively**		203	10.6	4.8
Worn Excessively	130			
Noisy	45			
Vibration Excessive	17			
Burred	4			
Excessive Hum	4			
Chattering	2			
Deteriorated	1			
F. **Corroded**		107	5.9	2.6
Corroded	107			
G. **Beyond Specified Tolerance**		13	0.7	0.3
Alignment Improper	10			
Adjustment Improper	2			
Beyond Specified Tolerance	1			
H. **Loose Nuts, Bolts, Screws**		11	0.6	0.3
Loose Nuts, Bolts, Screws	11			

TABLE 9. - Concluded

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
I. Overheats		4	0.2	0.1
Overheats	4			
J. Pressure Erratic		2	0.1	0.0
Erratic	1			
Pressure Erratic	1			
II. INDUCED FAILURE CAUSES (12.5%)		2,219	100.0	54.8
III. NO FAILURE CAUSES (44.0%)		7,827		
Scheduled Maintenance/ Time Change	4,208			
No Defect	2,355			
MWO Compliance	1,179			
Wrong Part	36			
To Facilitate Other Maintenance	27			
Cannibalization	14			
Troubleshooting	7			
MWO Not Applicable	1			
IV. UNKNOWN CAUSES (33.2%)		5,910		

TABLE 10. 42-DEGREE GEARBOX REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 204-040-003-13, -23, -29, -37

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)			15,466		
I. INHERENT FAILURE CAUSES (22.4%)		3,453		100.0	68.7
A. Leaking	2,148			62.2	42.7
Leaking	2,081				
Oil Leak	62				
Seal Blown	3				
Grease Leakage	1				
Seal Leakage	1				
B. Worn Excessively	649			18.8	12.9
Worn Excessively	455				
Chipped	57				
Noisy	39				
Vibration Excessive	32				
Bearing Failure	20				
Scored	11				
Loose	9				
Deteriorated	5				
Burred	5				
Excessive Hum	4				
Pitted	3				
Chattering	2				
Grooved	2				
Blacklash High	1				

TABLE 10. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
Elongated	1			
Flaking	1			
High-Frequency Vibration	1			
Slippage	1			
C. <u>Contamination</u>		256	7.4	5.1
Metal on Magnetic Plug	88			
Dirty	55			
Contamination	55			
Impending or Incipient Failure Indicated by Spectrometric Oil Analysis	51			
Oil Contamination	4			
Contaminated with Metal	3			
D. <u>Broken</u>		190	5.5	3.8
Broken	127			
Cracked	51			
Collapsed	12			
E. <u>Internal Failure</u>		159	4.6	3.2
Internal Failure	143			
Mechanical Binding	5			
Seized	5			
Jammed	4			
Binding	2			

TABLE 10. - Continued

	Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
	F. <u>Overheats</u>	26	0.8	0.5
	Overheats	25		
	Burned Out	1		
	G. Corroded	15	0.4	0.3
	Corroded	15		
	H. <u>Beyond Specified Tolerance</u>	8	0.2	0.2
	Warped	3		
	Out of Adjustment	3		
	Beyond Specified Tolerance	2		
	I. <u>Loose Bolts, Nuts, Screws</u>	2	0.1	0.0
	Loose Bolts, Nuts, Screws	2		
II.	INDUCED FAILURE CAUSES (10.2%)	1,575	100.0	31.3
III.	NO FAILURE CAUSES (33.3%)	5,140		
	Scheduled Maintenance/Time Change	2,565		
	No Defect	2,354		
	MWO Compliance	87		
	To Facilitate Other Maintenance	73		
	Cannibalization	40		

TABLE 10. - Concluded

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
Troubleshooting	20		
Partial MWO Compliance	1		
IV. UNKNOWN CAUSES (34.2%)	5,278		

TABLE 11. 90-DEGREE GEARBOX REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 204-040-012-1, -7, -13
209-040-400-11

Reason for Removal	Number of Assemblies				% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)				17,061		
I. INHERENT FAILURE CAUSES (25.2%)			4,296		100.0	75.1
A. <u>Leaking</u>		2,083			48.5	36.4
Leaking	2,027					
Oil Leak	54					
Seal Blown	1					
Seal Broken	1					
B. <u>Contamination</u>		859			20.0	15.0
Metal on Magnetic Plug	333					
Impending or Incipient Failure Indicated By Spectrometic Oil Analysis	247					
Dirty	154					
Contamination	115					
Oil Contamination	8					
Fails Diagnostic	2					
C. <u>Excessive Wear</u>		847			19.7	14.8
Worn Excessively	560					
Chipped	159					

TABLE 11. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
Vibration Excessive	32			
Noisy	18			
Bearing Failure	17			
Loose	11			
Scored	11			
High-Frequency Vibration	10			
Grooved	5			
Deteriorated	5			
Burred	5			
Nicked	5			
Pitted	3			
Chattering	2			
Backlash High	1			
Excessive Play	1			
Excessive Hum	1			
D. Internal Failure		244	5.7	4.3
Internal Failure	227			
Jammed	5			
Mechanical Binding	4			
Seized	4			
Binding	3			
Controls, Inoperative	1			
E. Broken		217	5.1	3.8
Broken	164			
Cracked	37			

TABLE 11. - Continued

Reason for Removal	Number of Assemblies			% of Major Cause	% of All Failure
Collapsed	11				
Burst	5				
F. Corroded		20		0.5	0.3
Corroded	20				
G. Loose Bolts, Nuts, Screws		9		0.2	0.2
Loose Bolts, Nuts, Screws	9				
H. Beyond Specified Tolerance		11		0.3	0.2
Out of Adjustment	6				
Beyond Specified Tolerance	4				
Warped	1				
I. Overheats		6		0.1	0.1
Overheats	5				
Burned Out	1				
II. INDUCED FAILURE CAUSES (8.3%)			1,424	100.0	24.9
III. NO FAILURE CAUSES (34.5%)			5,888		
Scheduled Maintenance/ Time Change		3,151			
No Defect		2,294			

TABLE 11. - Concluded

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
MWO Compliance	178		
To Facilitate Other Maintenance	128		
Cannibalization	64		
Wrong Part	39		
Troubleshooting	30		
MWO Previously Complied With	4		
IV. UNKNOWN CAUSES (32.0%)	5,453		

TABLE 12. UH-1B/D/H TYPE MAIN ROTOR HUB REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 204-011-101-1, -3, -5, -9, -11
204-012-101-3, -5

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)			20,955		
I. INHERENT FAILURE CAUSES (23.1%)		4,848		100.0	75.2
A. Worn Excessively	1,127			23.3	17.5
Worn Excessively	587				
Bearing Failure	185				
Chipped	136				
Scored	84				
Loose	59				
Grooved	40				
Pitted	17				
Burred	7				
Slippage	7				
Deteriorated	3				
Noisy	1				
Elongated	1				
B. Leakage	3,076			63.5	47.7
Leaking	2,958				
Oil Leak	113				
Seal Blown	3				
Leaks Oil	2				

TABLE 12. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
C. Broken		155	3.2	2.4
Broken	78			
Collapsed	42			
Cracked	22			
Burst	13			
D. Internal Failure		211	4.4	3.3
Internal Failure	170			
Seized	12			
Fails Diagnostic	10			
Jammed	10			
Binding	5			
Mechanical Binding	2			
Brittle	2			
E. Beyond Specified Tolerance		113	2.3	1.8
Adjustment Improper	61			
Alignment Improper	24			
Out of Adjustment	22			
Beyond Specified Tolerance	6			
F. Unbalanced		37	0.8	0.6
Unbalanced	26			
Unstable	10			
Erratic	1			

TABLE 12. - Continued

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
G. <u>Contamination</u>		37		0.8	0.6
Contamination	26				
Dirty	11				
H. <u>Corroded</u>		28		0.6	0.4
Corroded	28				
I. <u>Unable To Adjust Limits</u>		31		0.6	0.5
Unable To Adjust Limits	27				
Improper Tracking	4				
J. <u>Bent</u>		26		0.5	0.4
Warped	11				
Sprung	9				
Bent	6				
K. <u>Loose Nuts, Bolts, Screws</u>		7		0.1	0.1
Loose Nuts, Bolts, Screws	7				
II. INDUCED FAILURE CAUSES (7.6%)			1,600	100.0	24.8
III. NO FAILURE CAUSES (26.4%)			5,540		
No Defect		2,597			

TABLE 12. - Concluded

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
Scheduled Maintenance/ Time Change	2,343		
To Facilitate Other Maintenance	264		
Troubleshooting	126		
MWO Compliance	105		
Cannibalization	95		
Wrong Part	5		
MWO Previously Complied With	4		
Partial MWO Compliance	1		
IV. UNKNOWN CAUSES (42.8%)	8,967		

TABLE 13. UH-1C/AH-1G TYPE MAIN ROTOR HUB REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 540-011-101-1, -3, -5, -7, -9

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)			5,357		
I. INHERENT FAILURE CAUSES (26.0%)		1,393		100.0	70.8
A. <u>Worn Excessively</u>		978		70.2	49.7
Worn Excessively	595				
Bearing Failure	286				
Loose	40				
Chipped	26				
Scored	11				
Slippage	9				
Noisy	4				
Deteriorated	2				
Chattering	1				
Burred	1				
Excessive Play	1				
Flaking	1				
Pitted	1				
B. <u>Leakage</u>		31		2.2	1.6
Leaking	28				
Oil Leak	2				
Leaked (not electrically)	1				

TABLE 13. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
C. <u>Broken</u>		173	12.4	8.8
Cracked	99			
Broken	55			
Collapsed	19			
D. <u>Internal Failure</u>		122	8.8	6.2
Internal Failure	63			
Seized	23			
Mechanical Binding	15			
Binding	14			
Jammed	5			
Brittle	1			
Fused	1			
E. <u>Beyond Specified Tolerance</u>		45	3.2	2.3
Alignment Improper	18			
Adjustment Improper	14			
Out of Adjustment	10			
Beyond Specified Tolerance	3			
F. <u>Unbalanced</u>		12	0.9	0.6
Unbalanced	8			
Unstable	3			
Erratic	1			

TABLE 13. - Continued

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
G. <u>Contamination</u>		6		0.4	0.3
Dirty	4				
Contamination	2				
H. <u>Corroded</u>		9		0.6	0.5
Corroded	9				
I. <u>Unable To Adjust Limits</u>		7		0.5	0.4
Unable To Adjust Limits	7				
J. <u>Bent</u>		10		0.7	0.5
Warped	7				
Bent	2				
Sprung	1				
II. INDUCED FAILURE CAUSES (10.7%)			574	100.0	29.2
III. NO FAILURE CAUSES (30.7%)			1,645		
No Defect		901			
Scheduled Maintenance/ Time Change		533			
To Facilitate Other Maintenance		72			
Cannibalization		48			

TABLE 13. - Concluded

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
Troubleshooting	44		
MWO Compliance	23		
Wrong Part	17		
MWO Previously Complied With	3		
MWO Not Applicable	2		
Not Damaged	1		
Partial MWO Compliance	1		
IV. UNKNOWN CAUSES (32.6%)	1,745		

TABLE 14. UH-1B/D/H TYPE SWASHPLATE REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 204-011-400-1, -3, -5, -7, -9, -11

Reason for Removal	Number	% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)	14,282		
I. INHERENT FAILURE CAUSES (17.4%)	2,487	100.0	68.2
A. Worn Excessively	2,068	83.2	56.7
Worn Excessively	1,412		
Bearing Failure	360		
Chipped	143		
Loose	67		
Scored	39		
Grooved	17		
Burred	11		
Beyond Specified Tolerance	8		
Noisy	3		
Brittle	2		
Pitted	2		
Unable To Adjust Limits	2		
Deteriorated	1		
End Play Excessive	1		
B. Broken	258	10.4	7.1
Broken	138		
Cracked	106		
Collapsed	14		

TABLE 14. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
C. <u>Leaking</u>		47	1.9	1.3
Leaking	47			
D. <u>Heat Damage</u>		34	1.4	0.9
Burned	28			
Heat Damage	4			
Overheats	2			
E. <u>Internal Failure</u>		22	0.9	0.6
Internal Failure	21			
Fails Diagnostic	1			
F. <u>Binding</u>		10	0.4	0.3
Mechanical Binding	5			
Seized	4			
Binding	1			
G. <u>Corroded</u>		14	0.6	0.4
Corroded	1[illegible]			
H. <u>Unbalanced</u>		6	0.2	0.2
Vibration Excessive	6			

TABLE 14. - Continued

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
I. <u>Bent</u>	10	0.4	0.3
Bent	6		
Sprung	2		
Warped	2		
J. <u>Contamination</u>	14	0.6	0.4
Contamination	10		
Dirty	4		
K. <u>Loose Nuts, Bolts, Screws</u>	4	0.2	0.1
Loose Nuts, Bolts, Screws	4		
II. INDUCED FAILURE CAUSES (8.1%)	1,158	100.0	31.8
III. NO FAILURE CAUSES (40.1%)	5,730		
Scheduled Maintenance/ Time Change	3,275		
No Defect	2,260		
To Facilitate Other Maintenance	83		
MWO Compliance	62		
Cannibalization	31		
Troubleshooting	8		
Wrong Part	6		

TABLE 14. - Concluded

Reason for Removal	Number of Assemblies	% of Major Cause Category	% of All Failure Causes
Engine Removed, Engine Modification	2		
MWO Previously Complied With	2		
Partial MWO Compliance	1		
IV. UNKNOWN CAUSES (34.4%)	4,907		

TABLE 15. UH-1C/AH-1G TYPE SWASHPLATE REMOVAL RECORDS CLASSIFIED BY REASON FOR REMOVAL

Part No. 209-010-400-1
540-011-450-3, -5, -7

Reason for Removal	Number of Assemblies			% of Major Cause Category	% of All Failure Causes
ALL CAUSES (100.0%)			3,611		
I. INHERENT FAILURE CAUSES (30.8%)		1,112		100.0	70.2
A. <u>Worn Excessively</u>		945		85.0	59.6
Worn Excessively	663				
Bearing Failure	79				
Chipped	63				
Grooved	45				
Scored	39				
Loose	27				
Beyond Specified Tolerance	7				
Unable To Adjust Limits	6				
Deteriorated	4				
Burred	3				
Pitted	3				
Noisy	2				
Brittle	2				
Excessive Play	1				
Flaking	1				
B. <u>Broken</u>		44		4.0	2.8
Broken	27				
Collapsed	10				
Cracked	7				

TABLE 15. - Continued

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
C. Leaking		24	2.2	1.5
Leaking	24			
D. Heat Damage		30	2.7	1.9
Burned	24			
Overheats	6			
E. Internal Failure		41	3.7	2.6
Internal Failure	37			
Fails Diagnostic	4			
F. Binding		5	0.4	0.3
Mechanical Binding	4			
Seized	1			
G. Corroded		7	0.6	0.4
Corroded	7			
H. Unbalanced		3	0.3	0.2
Vibration Excessive	3			
I. Bent		3	0.3	0.2
Bent	3			

TABLE 15. - Concluded

Reason for Removal	Number of Assemblies		% of Major Cause Category	% of All Failure Causes
J. Contamination		7	0.6	0.4
Contamination	5			
Dirty	2			
K. Loose Nuts, Bolts, Screws		3	0.3	0.2
Loose Nuts, Bolts, Screws	3			
II. INDUCED FAILURE CAUSES (1[illegible].1%)		473	100.0	29.8
[illegible]. NO FAILURE CAUSES ([illegible]7.9%)		1,009		
No Defect	534			
Scheduled Maintenance/ Time Change	417			
To Facilitate Other Maintenance	24			
Cannibalization	16			
MWO Compliance	10			
Troubleshooting	3			
Wrong Part	3			
MWO Previously Complied With	1			
Partial MWO Compliance	1			
IV. UNKNOWN CAUSES (28.2%)		1,017		

TABLE 16. WEIBULL DISTRIBUTION PARAMETERS FOR ALL FAILURES CAUSES OF ASSEMBLY REMOVAL FOR OVERHAUL

Assembly Drawing Numbers	β	θ	TBO	MTBR
42-Degree Gearbox 204-040-C03	1.134	1,405	1,500	951
90-Degree Gearbox 204-040-012 209-040-400	1.161	1,175	1,100	743
Main Transmission* 204-040-009 204-040-016 205-040-001	1.080	2,024	1,100	868
Main Rotor Hub 204-011-101 204-012-101	1.322	941	1,100	691
Main Rotor Hub 540-011-101	1.254	667	1,100	554
Swashplate 204-011-400	1.274	1,513	1,100	837
Swashplate 209-010-400 540-011-450	1.364	736	1,100	600

β = Weibull slope.

θ = Characteristic life.

TBO = Time between overhaul.

MTBR = Mean time between removals.

* TBO on the 204-040-016 main transmission has been extended to 1500 hours resulting in a MTBR value of 1,083 hours.

TABLE 17. DRIVE SYSTEM COMPONENT WEIBULL FAILURE MODE DISTRIBUTION CHARACTERISTICS

Component Failure Mode	Failure Code	β	θ	γ
MAIN TRANSMISSION 204-040-009 204-040-016 205-040-001				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	.97	97,672	0
Worn Excessively (2)	020	1.10	36,984	0
Broken (1)	070	1.30	19,725	0
Broken (2)	070	1.16	27,420	0
Corroded (1)	170	1.34	34,500	0
Corroded (2)	170	.92	191,314	0
Contamination (1)	306	1.12	17,700	0
Contamination (2)	306	1.13	9,791	0
Internal Failure (1)	374	1.20	31,298	0
Internal Failure (2)	374	.89	73,118	0
Leakage (1)	381	1.57	12,960	0
Leakage (2)	381	1.08	32,023	0
ALL INHERENT MODES (1)	-	1.19	6,103	0
ALL INHERENT MODES (2)	-	1.07	5,212	0
42-DEGREE GEARBOX 204-040-003				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.38	9,730	0
Worn Excessively (2)	020	1.08	10,526	0
Broken (1)	070	1.41	23,858	0
Broken (2)	070	.87	64,826	0
Contamination (1)	306	1.33	21,694	0
Contamination (2)	306	.82	77,196	0
Internal Failure (1)	374	1.53	15,081	0
Internal Failure (2)	374	1.14	59,706	0
Leakage (1)	381	1.17	4,702	0
Leakage (2)	381	1.17	3,586	0
Overheat (1)	481	.92	626,217	0
ALL INHERENT MODES (1)	-	1.23	3,037	0
ALL INHERENT MODES (2)	-	1.09	2,479	0

TABLE 17. - Continued

Component Failure Mode	Failure Code	β	θ	γ
90-DEGREE GEARBOX				
204-040-012-1, -7, -13				
209-040-400-11				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.14	13,098	0
Worn Excessively (2)	020	1.16	5,393	0
Broken (1)	070	.98	70,096	0
Broken (2)	070	1.09	25,053	0
Contamination (1)	306	1.38	8,092	0
Contamination (2)	306	1.06	6,789	0
Internal Failure (1)	374	1.22	22,560	0
Internal Failure (2)	374	1.08	31,901	0
Leakage (1)	381	1.49	3,186	0
Leakage (2)	381	1.11	3,198	0
ALL INHERENT MODES (1)	-	1.34	2,313	0
ALL INHERENT MODES (2)	-	1.11	1,577	0
MAIN ROTOR HUB				
204-011-101				
204-012-101				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.83	3,579	0
Worn Excessively (2)	020	1.43	3,211	0
Broken (1)	070	1.55	18,600	0
Broken (2)	070	1.08	32,200	0
Contamination (2)	306	1.04	167,480	0
Internal Failure (1)	374	1.60	11,634	0
Internal Failure (2)	374	1.25	17,730	0
Leakage (1)	381	1.65	2,320	0
Leakage (2)	381	1.28	1,738	0
Unable to Adjust Limits (1)	561	1.71	31,487	0
Unbalanced (1)	670	1.28	78,846	0
Beyond Specified Tolerance (1)	705	1.25	50,279	0
Beyond Specified Tolerance (2)	705	.68	495,380	0
Bent (1)	780	1.59	41,503	0
ALL INHERENT MODES (1)	-	1.66	1,735	0
ALL INHERENT MODES (2)	-	1.26	1,242	0

TABLE 17. - Continued

Component Failure Mode	Failure Code	β	θ	γ
<u>MAIN ROTOR HUB</u> (Cont'd) 540-011-101				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.83	1,561	0
Worn Excessively (2)	020	1.15	1,189	0
Broken (1)	070	1.48	5,500	0
Broken (2)	070	1.11	6,731	0
Internal Failure (1)	374	1.39	7,315	0
Internal Failure (2)	374	1.30	7,380	0
Leakage (1)	381	1.79	12,855	0
Leakage (2)	381	.88	71,200	0
Unbalanced (1)	670	.82	460,884	0
Beyond Specified Tolerance (1)	705	1.18	40,454	0
Beyond Specified Tolerance (2)	705	.62	328,862	0
ALL INHERENT MODES (1)	-	1.64	1,337	0
ALL INHERENT MODES (2)	-	1.12	917	0
<u>SWASHPLATE</u> 204-011-400				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.75	2,892	0
Worn Excessively (2)	020	1.30	2,127	0
Broken (1)	070	1.38	16,442	0
Broken (2)	070	1.03	18,385	0
Contamination (1)	306	1.46	75,488	0
Internal Failure (1)	374	1.41	72,245	100
Leakage (1)	381	1.19	103,229	0
Leakage (2)	381	.75	1,105,053	0
Heat Damage (1)	855	1.23	133,499	100
Heat Damage (2)	855	1.08	108,389	0
ALL INHERENT MODES (1)	-	1.66	2,706	0
ALL INHERENT MODES (2)	-	1.25	1,954	0
209-010-400 540-011-450				
INHERENT FAILURE MODE				
Worn Excessively (1)	020	1.63	1,340	0
Worn Excessively (2)	020	1.25	1,257	0
Broken (1)	070	1.02	34,788	100
Broken (2)	070	.94	35,565	0

TABLE 17. - Concluded				
Component Failure Mode	Failure Code	β	θ	γ
SWASHPLATE (Cont'd) 209-010-400 540-011-450				
Internal Failure (1)	374	1.80	6,631	0
Leakage (1)	381	.90	159,896	100
Heat Damage (1)	855	1.24	29,836	0
ALL INHERENT MODES (1)	-	1.62	1,215	0
ALL INHERENT MODES (2)	-	1.18	1,128	0

(1) First overhaul.
(2) Second and subsequent overhauls.
β Shape parameter, values are unitless.
θ Characteristic life, values are in hours.
γ Location parameter, values in hours, apparent starting point for the distribution.

TABLE 18. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - TRANSMISSION 204-040-016-1

ASSEMBLY: Transmission P/N: 204-040-016-1

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
GA3870	Bearing	2	8	-	-
GA5905	Outer Gerotor	1	2	-	3
GA5906	Inner Gerotor	1	9	9	3
GA5907	Gear Rotor Set	1	-	-	6
GA5909	Body Assembly	1	-	-	-
GA6209	Shaft	1	-	-	3
GC1507	Body Assembly	1	2	-	-
GC1669	Oil Pump	1	9	15	26
X1317204[4]	Clutch	1	24	20	12
X1342965[5]	Clutch	1			
204-040-103-7	Bevel Gear	1	19	19	18
204-040-104-13	Gear	1	15	11	15
204-040-108-7	Spur Gear	12	42	35	66
204-040-121-5	Spur Gearshaft	1	-	-	-
204-040-130-5	Shaft	12	0.6	-	-
204-040-132-1	Race	12	31	16	32
204-040-135-1	Bearing	3	20	23	32
204-040-143-1	Duplex Ball Bearing	3	22	14	27
204-040-166-3	Bearing Liner	1	-	-	-
204-040-168-1	Bearing Liner	1	-	-	-
204-040-170-5	Sleeve Bearing	2	-	-	-
204-040-190-7	Race	1	20	17	18
204-040-191-7	Race	1	19	9	12
204-040-197-3	Oil Pump Shaft	1	8	4	6
204-040-235-1	Sleeve Bushing	4	-	-	-
204-040-250-9	Sleeve Assembly	1	-	4	-

TABLE 18. - Continued

ASSEMBLY: Transmission P/N: 204-040-016-1

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-040-257-1	Liner	1	-	-	-
204-040-261-13	Jet #1	1	2	6	3
204-040-262-21	Jet #2	1	4	22	3
204-040-270-3	Bearing	1	19	11	18
204-040-271-1/-3	Bearing	1	19	20	29
204-040-274-1	Sleeve Liner	1	-	-	-
204-040-288-11	Jet #5	1	2	6	3
204-040-298-1	Oil Jet Assembly	1	2	11	3
204-040-305-1/-5	Sleeve Assembly	2	2	6	9
204-040-308-1	Centering Ring	1	2	-	-
204-040-310-1	Roller Cylinder Bearing	2	12	19	18
204-040-313-1	Ring	1	-	2	-
204-040-324-5	Shaft	1	4	8	12
204-040-326-7	Jet #3	1	6	9	3
204-040-327-1	Jet #6	1	2	7	6
204-040-330-3	Upper Sun Gear	1	77	72	79
204-040-331-5	Ring Gear Assy	1	37	28	47
204-040-336-1	Liner	1	-	-	-
204-040-337-1	Liner	1	-	-	-
204-040-338-1	Liner	1	-	-	-
204-040-342-1	Ring	1	-	2	-
204-040-346-3	Bearing	1	6	-	-
204-040-353-23	Case Assembly	1	13	30	15
204-040-354-9	Case Assembly	1	11	7	15
204-040-355-5	Case Assembly	1	13	11	9
204-040-356-1	Sleeve	1	6	2	5

TABLE 18. - Continued

ASSEMBLY: Transmission P/N: 204-040-016-1

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-040-359-1	Case Assembly	1	43	57	41
204-040-360-3	Upper Planet Assembly	1	2	-	-
204-040-365-31	Dr. & Sump Assembly	1	-	-	-
204-040-386-1	Case Assembly	1	7	35	15
204-040-388-1	Jet Assembly	1	2	15	12
204-040-397-1	Spider Assembly	1	4	6	6
204-040-397-13	Web Assembly	1	-	-	-
204-040-430-1[6]	Housing	1	2	-	3
204-040-339-5	Housing	1			
204-040-700-1	Pinion Gear	1	24	24	21
204-040-701-3	Gear	1	9	15	18
204-040-725-1/-3	Roller Set	12	23	14	15
204-040-735-1	Sleeve Bushing	4	-	-	-
204-040-762-1	Spur Gear	1	6	7	18
204-040-763-1	Xmsn Spur Gear	1	6	13	21
204-040-784-1	Lower Planet Assembly	1	-	-	-
204-040-785-3	Spider	1	-	2	3
204-040-789-5	Planetary Ring	8	-	-	-
204-040-790-1	Sleeve Bushing	4	-	-	-
205-040-134-1	Housing	2	-	-	-
205-040-135-1	Jet	2	-	4	4
205-040-229-1[7]	Lower Sun Gear	1	26	30	24
204-040-329-1	Lower Sun Gear	1			
205-040-232-1	Liner	1	-	-	3
205-040-242-1[8]	Bearing	2	49	34	30
204-040-142-1[4]	Bearing	2			
205-040-246-1[9]	Bearing	1	28	17	9
204-040-346-3[4]	Bearing	1			

TABLE 18. - Concluded

ASSEMBLY: Transmission P/N: 204-040-016-1

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
205-040-246-1	Bearing	1	2	-	6
205-040-249-1[10]	Bearing	1	22	17	24
204-040-269-3[4]	Bearing	1			
205-040-425-1	Bearing	1	-	-	-
209-040-725-1	Roller Set	12	2	-	-
21-008-12-16	Sleeve Bushing	1	-	-	-
21-008-12-24	Sleeve Bushing	1	-	-	-
22-012-35-28-34	Sleeve Bushing	2	-	-	-
22-014-47-58-34	Sleeve Bushing	1	-	-	-
465C62NSW	Globe Valve	1	7	20	21

[1]Total of sample of first overhaul assemblies = 54.

[2]Total of sample of second & subsequent overhaul assemblies = 55 (54 second, 1 third).

[3]Total of sample of assemblies removed for critical failure codes = 34.

[4]Used on or with input quill assembly (P/N 204-040-363-3).

[5]Used on input quill assembly (P/N 205-040-263-3) and replaces P/N X131720.

[6]Replaces P/N 204-040-339-5

[7]Replaces P/N 204-040-329-1

[8]Replaces P/N 204-040-142-1 and used on quill assembly P/N 205-040-263-3.

[9]Replaces P/N 204-040-345-7 and used on input quill P/N 205-040-263-3.

[10]Replaces P/N 204-040-269-3 and used with input quill P/N 205-040-263-3.

TABLE 19. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - TRANSMISSION 204-040-016-5

ASSEMBLY: Transmission P/N: 204-040-016-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
GA3870	Bearing	2	-	-	-
GA5905	Outer Gerotor	1	9	-	-
GA5906	Inner Gerotor	1	-	-	-
GA5907	Gear Rotor Set	1	-	9	-
GA5909	Body Assembly	1	-	-	-
GA6209	Shaft	1	3	-	-
GC1507	Body Assembly	1	-	-	-
GC1669	Oil Pump	1	9	16	-
X131720	Clutch	1	16	-	-
204-040-103-7	Bevel Gear	1	16	31	-
204-040-104-13	Gear	1	9	25	-
204-040-108-7	Spur Gear	12	43	38	-
204-040-121-5	Spur Gearshaft	1	-	-	-
204-040-130-5	Shaft	12	0.3	0.3	-
204-040-132-1	Race	12	39	16	-
204-040-135-1	Bearing	3	25	-	-
204-040-143-1	Duplex Ball Bearing	3	25	31	
204-040-166-3	Bearing Liner	1	-	-	-
204-040-168-1	Bearing Liner	1	-	-	-
204-040-170-5	Sleeve Bearing	2	-	-	-
204-040-185-3	Ring	1	3	-	-
204-040-190-7	Race	1	3	-	-
204-040-191-7	Race	1	13	-	-
204-040-197-3	Oil Pump Shaft	1	6	6	-
204-040-235-1	Sleeve Bushing	4	-	-	-
204-040-250-9	Sleeve Assembly	1	-	6	-

TABLE 19. - Continued

ASSEMBLY: Transmission P/N: 204-040-016-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-040-257-1	Liner	1	3	3	-
204-040-261-13	Jet #1	1	-	-	-
204-040-262-21	Jet #2	i	-	9	-
204-040-270-3	Bearing	1	16	6	-
204-040-271-3	Bearing	1	25	22	-
204-040-274-1	Sleeve Liner	1	-	-	-
204-040-288-11	Jet #5	1	-	-	-
204-040-298-1	Oil Jet Assembly	1	3	6	-
204-040-305-1	Sleeve Assembly	2	3	8	-
204-040-310-1	Roller Cylinder Bearing	2	13	11	-
204-040-313-1	Ring	1	3	3	-
204-040-324-5	Shaft	1	6	3	-
204-040-326-7	Jet #3	1	3	3	-
204-040-327-1	Jet #6	1	3	6	-
204-040-330-3	Upper Sun Gear	1	75	56	-
204-040-331-5	Ring Gear Assy	1	38	28	-
204-040-336-1	Liner	1	-	3	-
204-040-337-1	Liner	1	3	-	-
204-040-338-1	Liner	1	3	-	-
204-040-342-1	Ring	1	3	-	-
204-040-346-3	Bearing	1	3	-	-
204-040-353-23	Case Assembly	1	19	19	-
204-040-354-9	Case Assembly	1	19	3	-
204-040-355-5	Case Assembly	1	3	13	-
204-040-356-1	Sleeve	1	-	3	-
204-040-359-1	Case Assy	1	38	53	-
204-040-360-3	Upper Planet Assembly	1	-	-	-
204-040-365-31	Dr. & Sump Assembly	1	3	-	-

TABLE 19. - Continued

ASSEMBLY: Transmission P/N: 204-040-016-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-040-386-1	Case Assembly	1	25	31	-
204-040-388-1	Jet Assembly	1	-	3	-
204-040-397-1	Spider Assembly	1	-	-	-
204-040-397-13	Web Assembly	1	-	-	-
204-040-399-7	Sleeve	1	3	-	-
204-040-430-1	Housing	1	-	28	-
204-040-609-1	Ring	1	3	-	-
204-040-700-1	Pinion Gear	1	25	-	-
204-040-701-3	Gear	1	19	22	-
204-040-725-1/-3	Roller Set	12	23	21	-
204-040-735-1	Sleeve Bushing	4	-	-	-
204-040-762-1	Spur Gear	1	16	3	-
204-040-763-1	Xmsn Spur Gear	1	16	16	-
204-040-784-1	Lower Planet Assembly	1	-	-	-
204-040-785-3	Spider	1	-	3	-
204-040-789-5	Planetary Ring	8	-	-	-
204-040-790-1	Sleeve Bushing	4	-	-	-
205-040-134-1	Housing	2	-	3	-
205-040-135-1	Jet	2	-	2	-
205-040-229-1[4]	Lower Sun Gear	1	22	97	-
204-040-329-1	Lower Sun Gear	1			
205-040-232-1	Liner	1			
205-040-242-1[6]	Bearing	2	47	-	-
204-040-142-1[5]	Bearing	2			
205-040-246-1[7]	Bearing Duplex	1	38	97	-
204-040-346-3[5]	Bearing Duplex	1			
205-040-249-1[8]	Bearing	1	22	97	-
204-040-269-3[5]	Bearing	1			

TABLE 19. - Concluded

ASSEMBLY: Transmission P/N: 204-040-016-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
205-040-425-1	Bearing	1	-	-	-
209-040-725-1	Roller Set	12	-	1	-
21-008-12-16	Sleeve Bushing	1	-	-	-
21-008-12-24	Sleeve Bushing	1	-	-	-
22-012-35-28-34	Sleeve Bushing	2	-	-	-
22-014-47-58-34	Sleeve Bushing	1	-	-	-
465C62NSW	Globe Valve	1	16	3	-

[1]Total sample of first overhaul assemblies = 32.

[2]Total sample of second overhaul assemblies = 32.

[3]No data in sample.

[4]Replaces P/N 204-040-329-1.

[5]Used on or with input quill assembly P/N 204-040-363-3.

[6]Replaces P/N 204-040-142-1 and used on input quill assembly P/N 205-040-263-3.

[7]Replaces P/N 204-040-345-7 and used on input quill assembly P/N 205-040-263-3.

[8]Replaces P/N 204-040-269-3 and used with input quill assembly P/N 205-040-263-3.

TABLE 20. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - 42-DEGREE GEARBOX 204-040-003-37

ASSEMBLY: 42-Degree Gearbox Assembly P/N: 204-040-003-37

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-001-752-1	Strip	1	-	10	-
204-040-003-33	Quill Assembly	1	-	-	-
204-040-003-35	Quill Assembly	1	-	-	-
204-040-143-1	Duplex Bearing	2	18	15	42
204-040-170-5	Sleeve Bearing	1	-	-	-
204-040-305-1	Sleeve Assembly	1	-	5	1
204-040-310-1	Roller Bearing	2	23	23	25
204-040-500-9	Bevel Gear	1	15	20	10
204-040-500-10	Bevel Gear	1	15	20	18
204-040-513-1	Case Assembly	1	10	10	8
204-040-603-7	Coupling	2	15	18	11
204-040-604-5	Coupling	2	5	3	2

[1] Total of sample of first overhaul assemblies = 20.

[2] Total of sample of second overhaul assemblies = 20.

[3] Total of sample of assemblies removed for critical failure codes = 50.

TABLE 21. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - 90-DEGREE GEARBOX 204-040-012-13

ASSEMBLY: 90-Degree Gearbox   P/N: 204-040-012-13

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-040-143-1	Bearing	1	30	55	27
204-040-400-7	Pinion	1	27	12	28
204-040-401-5	Gear	1	36	18	32
204-040-402-7	Shaft	1	3	9	11
204-040-406-1	Bearing	1	18	45	15
204-040-407-3	Bearing	1	18	30	13
204-040-417-1	Liner	1	-	-	-
204-040-418-13	Case Assembly	1	12	18	7
204-040-423-1	Sleeve Assembly	1	9	21	5
204-040-424-1	Bearing	1	33	48	32
204-040-422-1	Pin	1	-	-	1
204-040-425-1	Sleeve Assembly	1	-	12	4
204-040-603-7	Coupling	1	3	9	5
204-040-604-5	Coupling	1	15	32	15

[1]Total of sample of first overhaul assemblies = 33.

[2]Total of sample of second and subsequent overhaul assemblies = 34 (33 second, 1 third).

[3]Total of sample of assemblies removed for critical failure codes = 75.

TABLE 22. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - MAIN ROTOR HUB INITIALLY 204-011-101-9 or -11

ASSEMBLY: Main Rotor Hub Assembly　　P/N: 204-011-101-9/-11

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-010-170-5	Sleeve Bushing	4	7	-	-
204-010-170-7	Sleeve Bushing	4	13	-	-
204-010-170-9	Sleeve Bushing	2	13	-	-
204-010-413-27	Sleeve Bushing	4	48	-	50
204-010-413-29	Sleeve Bushing	4	63	-	40
204-011-102-1	Yoke Assembly	1	-	-	-
204-011-103-1	Trunnion Assembly	1	-	-	-
204-011-105-1	Trunnion Assembly	1	27	-	30
204-011-108-1	Pillow Block	2	30	3	50
204-011-110-3	Bearing	2	93	20	95
204-011-111-1	Bearing	2	97	20	85
204-011-112-1	Bearing	2	90	20	90
204-011-113-1[4]	Strap	2	100	60	-
204-011-120-5	Pitch Horn Assembly	2	13	-	45
204-011-121-1	Grip Assembly	2	-	-	25
204-011-121-5	Grip Assembly	2	20	-	-
204-011-122-1	Liner Assembly	2	3	-	15
204-011-129-1	Sleeve Bushing	2	10	-	10
204-011-130-1	Bearing Housing Liner	2	10	-	-
204-011-135-3	Bushing	4	17	7	15
204-011-140-1	Drag Brace Assembly	2	-	-	-
204-011-142-3	Rod End Clevis	2	-	-	55
204-011-143-1	Threaded End Rod	2	47	33	40

TABLE 22. - Concluded

ASSEMBLY: Main Rotor Hub Assembly P/N: 204-011-101-9/-11

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-011-151-1	Blade Bolt	2	63	70	-
204-011-179-1	Rod End Clevis	2	-	-	-

[1]Total of sample of first overhaul assemblies = 15.

[2]Total of sample of second overhaul assemblies = 15.

[3]Total of sample of assemblies removed for critical failure codes = 10.

[4]Retirement interval is 1100 hours.

TABLE 23. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - MAIN ROTOR HUB INITIALLY 204-012-101-3 or -5

ASSEMBLY: Main Rotor Hub Assembly P/N: 204-012-101-3/-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-010-170-5	Sleeve Bushing	4	6	-	7
204-010-170-7	Sleeve Bushing	4	7	-	5
204-010-170-9	Sleeve Bushing	2	11	-	9
204-010-413-27	Sleeve Bushing	4	24	2	19
204-010-413-29	Sleeve Bushing	4	38	7	34
204-011-102-17	Yoke Assembly	1	47	3	20
204-011-105-1	Trunnion	1	17	3	28
204-011-108-1	Pillow Block	2	11	4	30
204-011-110-1	Bearing	2	-	5	2
204-011-110-3	Bearing	2	86	64	95
204-011-111-1	Bearing	2	80	61	97
204-011-112-1	Bearing	2	82	57	92
204-011-120-1	Pitch Horn Assembly	2	3	-	-
204-011-120-5	Pitch Horn Assembly	2	5	4	16
204-011-121-1	Grip Assembly	2	2	-	2
204-011-121-5	Grip Assembly	2	13	5	31
204-011-122-1	Liner Assembly	2	5	3	12
204-011-129-1	Sleeve Bushing	2	32	2	29
204-011-130-1	Bearing Housing Liner	2	31	2	30
204-011-135-3	Bushing	4	7	0.3	17
204-011-140-1	Drag Brace Assembly	2	-	-	-
204-011-142-3	Clevis	2	-	-	33
204-011-143-1	Threaded Rod End	2	23	8	35
204-011-148-1	Main Rotor Yoke Ring	2	2	-	-
204-011-151-1	Blade Bolt	2	67	39	-
204-011-160-1	Sleeve	2	-	2	2

TABLE 23. - Concluded

ASSEMBLY: Main Rotor Hub Assembly P/N: 204-012-101-3/-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-011-171-3	Bolt	4	3	-	-
204-011-179-1	Rod End Clevis	2	-	-	2
204-012-104-5[4]	Strap Pin	2	11	-	-
204-012-107-1	Sleeve	2	11	0.8	5
204-012-109-1	Worm Gear	2	-	-	-
204-012-112-5[4]	Strap	2	30	44	-

[1]Total of sample of first overhaul assemblies = 66.

[2]Total ot sample of second overhaul assemblies = 66.

[3]Total of sample of assemblies removed for critical failure codes = 64.

[4]Retirement interval is 2200 hours.

TABLE 24. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - MAIN ROTOR HUB INITIALLY 540-011-101-5

ASSEMBLY: Main Rotor Hub Assembly P/N: 540-011-101-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-012-112-7[4]	Strap	2	9	14	-
209-010-108-3	Bushing Sleeve	2	11	11	3
209-010-108-4	Bushing Sleeve	2	7	5	3
209-010-109-1	Pitch Horn Assembly	2	18	-	47
209-010-111-1	Bushing	4	27	-	49
209-010-111-3	Bushing	2	32	-	53
540-011-102-5[5]	Yoke Assembly	1	9	5	3
540-011-106-5	Housing Assembly	2	-	-	16
540-011-109-5	Housing Assembly	2	5	-	34
540-011-110-9	Bearing	2	86	5	64
540-011-110-11	Sleeve Bearing	2	68	5	67
540-011-110-13	Bearing	2	86	91	59
540-011-116-1	Drag Brace Assembly	2	-	-	-
540-011-117-1	Clevis	2	-	-	27
540-011-117-3	Clevis Rod End	2	-	-	23
540-011-118-1	Barrel Assembly	2	23	9	31
540-011-119-19	Bolt	2	23	21	-
540-011-131-7	Bushing	2	-	-	16
540-011-143-9	Sleeve	2	64	90	59
540-011-143-11	Sleeve	1	86	-	41
540-011-143-13	Sleeve	1	77	-	44
540-011-150-3	Trunnion	1	-	-	-
540-011-150-5	Main Rotor Trunnion	1	-	8	22
540-011-153-13[5]	Extension Assembly	2	-	-	-
540-011-153-15[5]	Extension Assembly	2	-	-	19
540-011-154-5	Grip Assembly	2	-	-	-

TABLE 24. - Concluded

ASSEMBLY: Main Rotor Hub Assembly P/N: 540-011-101-5

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
540-011-161-1	Bushing	8	2	-	-
540-011-161-3	Sleeve Bushing	4	5	2	-

[1]Total of sample of first overhaul assemblies = 22.

[2]Total of sample of second and subsequent overhaul assemblies = 23 (22 second, 1 third).

[3]Total of sample of assemblies removed for critical failure codes = 32.

[4]Retirement interval is 2200 hours.

[5]Retirement interval is 3300 hours.

TABLE 25. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - MAIN ROTOR HUB 540-011-101-9

ASSEMBLY: Main Rotor Hub Assembly P/N: 540-011-101-9

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-012-112-7[4]	Strap	2	19	27	-
209-010-108-3	Bushing	1	4	-	-
540-011-102-5[5]	Yoke Assembly	1	14	16	11
540-011-106-5	Housing Assembly	2	8	11	16
540-011-106-7	Trunnion	2	-	-	-
540-011-109-1	Housing	2	6	-	5
540-011-109-5	Housing	2	12	3	8
540-011-110-5	Bearing	1	-	-	11
540-011-110-9	Sleeve Bearing	2	79	8	79
540-011-110-11	Sleeve Bearing	2	75	6	68
540-011-110-13	Sleeve Bearing	2	88	60	95
540-011-116-1	Drag Brace Assembly	2	-	-	-
540-011-117-1	Rod End Clevis	2	33	5	-
540-011-117-2	Clevis	1	2	-	11
540-011-117-3	Rod End	2	23	3	3
540-011-118-1	Barrel Assembly	2	23	1	24
540-011-119-19	Bolt	2	34	8	-
540-011-131-7	Sleeve Bushing	2	22	2	11
540-011-143-9	Sleeve	2	70	43	74
540-011-143-11	Sleeve	2	56	-	66
540-011-143-13	Sleeve	2	54	-	68
540-011-147-1	Pitch Horn Assembly	2	11	2	5
540-011-149-1	Sleeve Bushing	4	-	-	-
540-011-149-3	Sleeve Bushing	4	-	-	-
540-011-150-3	Trunnion	1	-	-	-
540-011-150-5	Trunnion	1	12	12	47

TABLE 25. - Concluded

ASSEMBLY: Main Rotor Hub Assembly P/N: 540-011-101-9

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
540-011-153-13[5]	Extension Assembly	2	-	-	3
540-011-153-15[5]	Extension Assembly	2	7	4	3
540-011-154-5	Grip Assembly	2	-	2	-
540-011-161-1	Sleeve Bushing	8	0.5	1	1
540-011-161-3	Bushing	4	-	-	3

[1]Total of sample of first overhaul assemblies = 50.

[2]Total of sample of second overhaul assemblies = 50.

[3]Total of sample of assemblies removed for critical failure codes = 19.

[4]Retirement interval is 2200 hours.

[5]Retirement interval is 3300 hours.

TABLE 26. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - SWASHPLATE 204-011-400-11

ASSEMBLY: Swashplate & Support P/N: 204-011-400-11

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
AN200KP5	Ball Bearing	4	33	34	26
KSP9001	Trunnion Assembly	5	0.3	-	50
204-010-404-1	Gimbal Ring	1	-	4	-
204-010-404-3	Ring	1	16	39	6
204-010-413-1	Sleeve Bushing	2	-	1	-
204-010-413-15	Sleeve Bushing	2	6	12	-
204-010-413-29	Sleeve Bushing	2	0.4	-	-
204-010-413-31	Sleeve Bushing	2	11	9	19
204-010-413-35	Sleeve Bushing	2	5	5	6
204-010-413-37	Sleeve Bushing	4	3	6	3
204-010-413-39	Sleeve Bushing	2	12	8	9
204-010-433-1	Bearing Liner Assembly	4	1	4	3
204-011-402-5	Inner Ring Assembly	1	1	-	-
204-011-402-13	Ring Assembly	1	6	1	13
204-011-403-1	Outer Ring Assembly	1	7	5	6
204-011-404-5[4]	Support Assembly	1	13	4	6
204-011-423-1	Sleeve	1	44	19	31
204-011-425-1	Liner	1	32	12	44
204-011-427-1	Inner Race	1	1	-	-
204-011-428-3	Bearing Cover	1	1	-	-
204-011-430-1	Bearing	1	61	61	50
204-011-451-1	Trunnion Assembly	5	42	34	36
204-011-454-1	Lockplate	1	-	4	-
204-011-458-1	Swashplate Plate	4	19	1	-
204-011-458-3	Swashplate Plate	4	-	0.2	-
204-011-458-5	Swashplate Plate	1	-	1	-

TABLE 26. - Concluded

ASSEMBLY: Swashplate & Support

P/N: 204-011-400-11

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd & Subs. Overhauls[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-011-458-7	Swashplate Plate	1	46	3	-
22-010-31-34-24	Sleeve Bushing	2	5	10	-

[1] Total of sample of first overhaul assemblies = 140.

[2] Total of sample of second overhaul assemblies = 140.

[3] Total of sample of assemblies removed for critical failure codes = 16.

[4] Retirement interval is 3300 hours.

TABLE 27. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - SWASHPLATE 209-010-400-1

ASSEMBLY: Swashplate & Support P/N: 209-010-400-1

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-011-423-1	Sleeve	1	35	21	12
204-011-430-1	Bearing	1	64	68	70
209-010-402-1[4]	Inner Ring Assembly	1	6	7	6
209-010-403-1[4]	Outer Ring Assembly	1	6	7	3
209-010-404-1	Support Assembly	1	64	18	64
209-010-418-1	Bushing	3	12	22	26
209-010-418-3	Bushing	1	13	23	24
209-010-419-1	Bushing	1	14	22	24
540-011-381-1	Bushing	4	-	0.5	-
540-011-411-3	Ring	1	4	1	-
540-011-419-13	Bushing	1	77	72	73
540-011-424-1	Ring	1	36	28	-
540-011-425-1	Ring	1	5	6	-
540-011-455-1	Bearing	1	14	11	12
540-011-462-1	Bearing Set	1	8	23	9
540-011-479-1	Sleeve Bearing	1	41	27	21

[1]Total of sample of first overhaul assemblies = 107.

[2]Total of sample of second overhaul assemblies = 107.

[3]Total of sample of assemblies removed for critical failure codes = 33.

[4]Retirement interval is 3300 hours.

TABLE 28. PERCENTAGE OF PARTS REPLACED DURING OVERHAUL - SWASHPLATE 540-011-450-7

ASSEMBLY: Swashplate & Support P/N: 540-011-450-7

Part Number	Nomenclature	QPA	% Replaced at 1st Overhaul[1]	% Replaced at 2nd Overhaul[2]	% Replaced from Assemblies Removed for Critical Failure Codes[3]
204-011-423-1	Sleeve	1	45	-	-
204-011-430-1	Bearing	1	45	45	-
540-011-381-1	Sleeve Bushing	4	30	30	-
540-011-403-9	Inner Ring Assembly	1	9	-	-
540-011-404-5	Ring Assembly	1	-	-	-
540-011-419-13	Bearing	1	73	73	-
540-011-452-5[4]	Support Assembly	1	82	55	-
540-011-455-1	Bearing	1	27	-	-
540-011-462-1	Bearing Set	1	18	27	-
540-011-479-1	Sleeve Bearing	1	43	9	-

[1]Total of sample of first overhaul assemblies = 11.

[2]Total of sample of second overhaul assemblies = 11.

[3]Total of sample of assemblies removed for critical failure codes = 0.

[4]Retirement interval is 1100 hours.

TABLE 29. MEAN TIME TO REMOVAL OF SEQUENTIAL OVERHAUL SAMPLE OF DRIVE SYSTEM ASSEMBLIES

Assembly Part Number	Previous Overhauls	MTR
TRANSMISSION		
204-040-016-1	0	814.6
	1	355.8
204-040-016-5	0	807.2
	1	330.2
42-DEGREE GEARBOX		
204-040-003-37	0	1216.6
	1	975.8
90-DEGREE GEARBOX		
204-040-012-13	0	804.7
	1	645.8
MAIN ROTOR HUB		
204-040-101-9/-11	0	1033.7
	1	330.3
204-040-012-3/-5	0	750.5
	1	307.5
540-011-101-5	0	521.9
	1	428.6
540-011-101-9	0	676.7
	1	330.6
SWASHPLATE		
204-011-400-11	0	889.3
	1	456.3
209-010-400-1	0	591.0
	1	358.4
540-011-450-7	0	706.1
	1	266.3

TABLE 30. MATERIAL FAILURE MISHAPS

Fleet Time 1/1/67-3/31/71	UH-1B				UH-1C				UH-1D				UH-1H				AH-1G			
	1,365,000				1,250,000				4,900,000				4,600,000				1,015,000			
	No. of Class 1-5	% of Total 1-5	No. of Class 6	% of Total 6	No. of Class 1-5	% of Total 1-5	No. of Class 6	% of Total 6	No. of Class 1-5	% of Total 1-5	No. of Class 6	% of Total 6	No. of Class 1-5	% of Total 1-5	No. of Class 6	% of Total 6	No. of Class 1-5	% of Total 1-5	No. of Class 6	% of Total 6
Aircraft Total	229	100.00	661	100.00	303	100.00	277	100.00	577	100.00	1232	100.00	890	100.00	1062	100.00	294	100.00	406	100.00
Main rotor hub	0	-	0	-	0	-	3	1.08	1	0.17	2	0.16	1	0.11	1	0.09	1	0.34	1	0.25
Swashplate	0	-	1	0.15	0	-	2	0.72	0	-	1	0.08	1	0.11	0	-	0	-	0	-
Main transmission	4	1.75	28	4.24	5	1.65	24	8.66	12	2.08	77	6.25	41	4.61	92	8.66	5	1.70	34	8.37
42° gearbox	3	1.31	0	-	1	0.33	1	0.36	3	0.52	11	0.89	6	0.67	1	0.09	1	0.34	1	0.25
90° gearbox	2	0.87	15	2.27	5	1.65	1	0.36	8	1.39	27	2.19	20	2.25	15	1.41	13	4.42	10	2.46

TABLE 31. MAIN TRANSMISSION FAILURE MODES THAT HAVE RESULTED IN FORCED LANDINGS OR WORSE MISHAPS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Transmission failure	2	3	4	14	-
Seal, O-ring, gasket failure					
Location unknown	-	-	2	11	-
Oil filter	-	-	-	-	1
Sump screen	1	-	-	-	-
Input quill	-	1	-	1	-
Oil line failure					
Location unknown	-	1	1	4	2
Contamination	-	-	1	1	-
Oil pressure low	-	-	1	-	-
Failure of					
Tail rotor output quill	-	-	2	7	-
Lower planetary	1	-	-	2	-
Reduction gear	-	-	-	1	-
Input quill	-	-	-	-	1
Oil line fitting	-	-	-	-	1
Oil jet	-	-	1	-	-
Totals	4	5	12	41	5

TABLE 32. MAIN TRANSMISSION FAILURE MODES THAT HAVE RESULTED IN PRECAUTIONARY LANDINGS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Seal, gasket, O-ring failures					
Location unknown	1	3	9	8	1
Oil filter	3	1	17	17	8
Input quill	1	1	3	7	2
Sump screen	-	1	-	8	-
Oil line	-	-	-	1	-
Oil line failures					
Location unknown	3	4	12	28	6
Oil cooler	-	2	-	-	4
Filter	1	1	-	-	-
Transmission failures	3	2	5	5	2
Instrument indications					
Oil pressure high, low or fluctuating	2	3	3	2	4
Oil temperature high	-	-	-	1	-
Chip detector	-	1	-	-	-
Electrical component failures					
Connectors	1	1	5	2	-
Oil pressure switch	2	-	2	-	-
Oil temperature switch	1	-	-	-	-

TABLE 32. - Continued

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Fitting failures					
Oil line	-	1	3	-	1
Oil filter	1	-	2	-	-
Quick disconnect	-	-	-	2	-
Oil pressure	1	-	-	-	-
Valve failures					
Drain valve	1	1	1	1	1
Thermal valve	-	-	-	1	1
Bypass valve	-	-	-	1	1
Oil pressure relief valve	-	-	1	-	-
Filter failure					
Loose	1	-	2	2	-
Undefined	2	-	1	-	-
Filter blew off	-	-	-	1	-
Strainer/screen	-	-	-	1	-
Input quill failures					
Shaft leaking	-	-	1	-	-
Housing	-	-	1	-	-
Contamination	1	-	2	3	-

TABLE 32. - Concluded

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Failure of					
Generator	-	-	3	-	-
Mast bearing	1	1	1	-	-
Oil jets	-	1	-	-	1
Oil pump	1	-	-	1	-
Bearing	-	-	1	-	1
Case	1	-	-	-	1
Pressure regulator	-	-	1	-	-
Lower planetary	-	-	1	-	-
Totals	28	24	77	92	34

TABLE 33. 42-DEGREE GEARBOX FAILURE MODES THAT HAVE RESULTED IN FORCED LANDINGS OR WORSE MISHAPS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Gearbox failure, cause unknown	2	1	1	3	-
Gearbox tore loose from aircraft	-	-	-	1	-
Failure of					
Input coupling	1	-	-	2	-
Output seal	-	-	1	-	-
Spline	-	-	1	-	-
Input bevel gear	-	-	-	-	1
Totals	3	1	3	6	1

TABLE 34. 42-DEGREE GEARBOX FAILURE MODES THAT HAVE RESULTED IN PRECAUTIONARY LANDINGS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Gearbox failure, cause unknown	-	1	3	-	1
Gearbox failure, metal clips on plug	-	-	2	1	-
Wire on plug broken	-	-	1	-	-
Failure of					
Output seal	-	-	1	-	-
Spline	-	-	1	-	-
Plug	-	-	1	-	-
Coupling	-	-	1	-	-
Gear	-	-	1	-	-
Totals	0	1	11	1	1

TABLE 35. 90-DEGREE GEARBOX FAILURE MODES THAT HAVE RESULTED IN FORCED LANDINGS OR WORSE MISHAPS

Failure modes	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Gearbox failure	2	2	3	6	7
Gearbox and tail rotor separated, cause unknown	-	2	1	9	2
Gearbox failed - tail rotor and gearbox separated from aircraft	-	1	2	1	4
Vibration, suspect gearbox failure	-	-	-	1	-
Failure of					
Gear	-	-	-	2	-
Input coupling	-	-	1	1	-
Quill Assembly	-	-	1	-	-
Totals	2	5	8	20	13

TABLE 36. 90-DEGREE GEARBOX FAILURE MODES THAT HAVE RESULTED IN PRECAUTIONARY LANDINGS

Failure Modes	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Gearbox failure	2	1	22	9	5
Chip detector light indication	10	-	-	-	-
Metal particles on plug	-	-	4	-	4
Vibration, suspected gearbox failure	1	-	-	-	-
Wire on plug loose	-	-	1	-	-
Binding, gearbox failure	1	-	-	-	-
Failure of					
Seal	-	-	-	4	-
Gear	-	-	-	2	-
Quill Assembly	1	-	-	-	-
Bearing, quill	-	-	-	-	1
Totals	15	1	27	15	10

TABLE 37. MAIN ROTOR HUB FAILURE MODES THAT HAVE RESULTED IN FORCED LANDINGS OR WORSE MISHAPS					
Failure modes	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Main rotor separated	-	-	-	1	1
Main rotor head controls	-	-	1	-	-
Totals	0	0	1	1	1

TABLE 38. MAIN ROTOR HUB FAILURE MODES THAT HAVE RESULTED IN PRECAUTIONARY LANDINGS					
Failure modes	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Worn grip bearing	-	-	-	-	1
Lost dust shield	-	1	-	-	-
Main rotor hub failure	-	1	-	-	-
Bearing sleeve failure	-	1	-	-	-
1 : 1 vibration	-	-	1	-	-
Rotor overspeed/excess play in hub	-	-	1	-	-
Grip seal leak	-	-	-	1	-
Totals	0	3	2	1	1

TABLE 39. SWASHPLATE AND SUPPORT FAILURE MODES THAT HAVE RESULTED IN FORCED LANDINGS OR WORSE MISHAPS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Defective trunnion in outer ring	-	-	-	1	-
Totals	0	0	0	1	0

TABLE 40. SWASHPLATE AND SUPPORT FAILURE MODES THAT HAVE RESULTED IN PRECAUTIONARY LANDINGS

Failure mode	Number of failures				
	UH-1B	UH-1C	UH-1D	UH-1H	AH-1G
Spring out of adjustment	1	-	-	-	-
Unibal required retorquing	-	1	-	-	-
Drive link bearing loose	-	1	-	-	-
Bushing sleeve failure	-	-	1	-	-
Totals	1	2	1	0	0

TABLE 41. PARTS SELECTED FOR FAILURE MODE STUDY CONSIDERATION BASED ON ASSEMBLY OVERHAUL PART REPLACEMENT DATA

Assembly / Part	Part No.	% Replaced From Assys Removed for Critical Failure Codes	Ratio of % Replaced*
Transmission	204-040-016-1		
Gear, Spur	204-040-108-7	79	1.06
Upper Sun Gear	204-040-330-3	66	1.72
Ring Gear Assembly	204-040-331-5	50	1.54
Gear Rotor Set	GA5907	6	∞
Shaft	GA6209	3	∞
Oil Pump	GC1669	26	2.16
42-Degree Gearbox	204-040-003-37		
Duplex Bearing	204-040-143-1	44	1.17
Case Assembly	204-040-513-1	8	∞
Coupling	204-040-603-7	11	∞
Coupling	204-040-604-5	2	∞
Main Rotor Hub Assembly	204-011-101-9/-11		
Sleeve Bushing	204-010-413-27	50	2.08
Sleeve Bushing	204-010-413-29	40	1.27
Trunnion Assembly	204-011-105-1	30	2.22
Pillow Block	204-011-108-1	50	3.03
Bearing	204-011-110-3	95	1.68
Bearing	204-011-111-1	85	1.45
Bearing	204-011-112-1	90	1.64
Pitch Horn Assembly	204-011-120-5	45	6.92
Grip Assembly	204-011-121-1	25	∞
Liner Assembly	204-011-122-1	15	10.00
Rod End Clevis	204-011-142-3	55	∞

TABLE 41. - Continued

Assembly / Part	Part No.	% Replaced From Assys Removed for Critical Failure Codes	Ratio of % Replaced*
Main Rotor Hub Assembly	204-012-101-3/-5		
Sleeve Bushing	204-010-413-29	34	1.51
Pillow Block	204-011-108-1	30	4.00
Bearing	204-011-110-3	95	1.27
Bearing	204-011-111-1	97	1.38
Bearing	204-011-112-1	92	1.32
Pitch Horn Assembly	204-011-120-5	16	3.56
Grip Assembly	204-011-121-5	31	3.44
Bearing Housing Liner	204-011-130-1	30	1.82
Bushing	204-011-135-3	17	4.66
Clevis	204-011-142-3	33	∞
Threaded Rod End	204-011-143-1	35	2.26
Rod End Clevis	204-011-179-1	2	∞
Main Rotor Hub Assembly	540-011-101-5		
Housing Assembly	540-011-106-5	16	∞
Bearing	540-011-110-9	70	1.58
Sleeve Bearing	540-011-110-11	70	1.95
Clevis	540-011-117-1	27	∞
Clevis Rod End	540-011-117-3	23	∞
Barrel Assembly	540-011-118-1	31	1.96
Bushing	540-011-131-7	16	∞
Sleeve	540-011-143-13	44	1.17
Main Rotor Tunnion	540-011-150-5	22	5.38
Extension Assembly	540-011-153-15	19	∞
Main Rotor Hub Assembly	540-011-101-9		
Bearing	540-011-110-5	11	∞
Sleeve Bearing	540-011-110-9	79	1.82
Sleeve Bearing	540-011-110-11	68	1.68

TABLE 41. - Concluded

Assembly / Part	Part No.	% Replaced From Assys Removed for Critical Failure Codes	Ratio of % Replaced*
Sleeve Bearing	540-011-110-13	95	1.28
Clevis	540-011-117-2	11	11.00
Sleeve	540-011-143-9	74	1.31
Sleeve	540-011-143-11	66	2.36
Sleeve	540-011-143-13	68	2.52
Trunnion	540-011-150-5	47	3.92
Extension Assembly	540-011-153-13	3	∞
Bushing	540-011-161-3	3	∞
Swashplate & Support Assembly	204-040-400-11		
Trunnion Assembly	KSP9001	50	333.33
Liner	204-011-425-1	44	2.00
Swashplate & Support Assembly	209-010-400-1		
Bearing	204-011-430-1	70	1.06
Support Assembly	209-010-404-1	64	1.56

* Percent replaced from assemblies removed for critical failure codes divided by percent replaced from sample of assemblies removed for first, second, and third overhauls.

TABLE 42. CONDITION CAUSING REPLACEMENT OF PARTS SELECTED FOR FAILURE MODES ANALYSIS

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
TRANSMISSION 204-040-016-1/-5 (34 Assemblies Reviewed)	SPUR GEAR 204-040-108-7	276	Debris Damage (Dented; Chipped/Dented; Dented/Spalled)	21.5
			Surface Compressive Failure (Spalled; Pitted)	78.5
	UPPER SUN GEAR 204-040-330-3	27	Surface Compressive Failure (Pitted/Spalling)	77.7
			Debris Damage (Dented/Pitted; Dented; Broken/Chipped; Spalled/Scored; Galled)	18.5
			Corrosion	3.7
	RING GEAR 204-040-331-5	17	Debris Damage (Dented; Broken/Chipped; Scored; Scored/Dented)	64.4
			Surface Compressive Failure (Pitted; Spalled)	35.2

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	FREEWHEELING CLUTCH ASSEMBLY X131720	7	Broken (Mutilated)	14.3
			Broken/Debris Damage (Metal in Oil)	14.3
			Missing	28.6
			Modification	42.8
	FREEWHEELING CLUTCH ASSEMBLY X134296	1	Broken/Debris Damage (Metal in Oil)	100.0

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
42-DEGREE GEARBOX 204-040-003-37 (48 Assemblies Reviewed)	DUPLEX BEARING 204-040-143-1	39	Excessive Wear	17.9
			Corrosion	10.2
			Debris Damage	66.7
			Internal Failure (Unknown)	5.1
	CASE ASSEMBLY 204-040-513-1	4	Deterioration (Cracked)	25.0
			Corrosion	75.0
	COUPLING 204-040-603-7	11	Surface Compressive Failure (Pitting)	9.1
			Excessive Wear (Worn, Separated)	54.5
			Debris Damage (Scored)	18.2
			Overheat (Overheat, Distorted)	18.2
MAIN ROTOR HUB ASSEMBLY 204-011-101-11 (10 Assemblies Reviewed)	SLEEVE BUSHING 204-010-413-27	20	Corrosion Pitting (Pitting)	100.0

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	SLEEVE BUSHING 204-010-413-29	16	Corrosion Pitting (Pitting)	87.5
			Quality Control Error (Oversized)	12.5
	TRUNNION 204-011-105-1	3	Pitting (Could be of either of the two modes)	100.0
	PILLOW BLOCK 204-011-106-1	10	Corrosion Pitting (Pitting)	100.0
	BEARING 204-011-110-3	19	Excessive Wear	31.5
			Modification	10.5
			Missing	5.3
			Overheat Pitting (Mechanical Damage)	52.6
	BEARING 204-011-111-1	17	Excessive Wear	35.2
			Missing	11.8
			Overheat (Distorted)	5.9

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Overheat Pitting (Mechanical Damage)	47.0
	BEARING 204-011-112-1	18	Excessive Wear	33.3
			Missing	11.1
			Overheat Pitting (Mechanical Damage)	55.6
	PITCH HORN ASSEMBLY 204-011-120-5	9	Corrosion Pitting (Pitting)	44.4
			Modification	11.1
			Unknown	22.2
			Loss of Torque (Mechanical Damage)	22.2
	GRIP ASSEMBLY 204-011-121-1	5	Corrosion Pitting (Pitting)	60.0
			Erosion Pitting (Mechanical Damage)	20.0

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Condemned (Scrapped, Specific reason not given)	20.0
	ROD END CLEVIS 204-011-142-3	11	Corrosion Pitting (Pitting)	100.0
<u>MAIN ROTOR HUB ASSEMBLY</u> 204-012-101-5	SLEEVE BUSHING 204-010-413-29	88	Corrosion Pitting (Pitting, Mechanical Damage)	100.0
(64 Assemblies Reviewed)	PILLOW BLOCK 204-011-108-1	39	Corrosion Pitting (Pitting)	79.5
			Missing	7.7
			Loss of Torque (Mechanical Damage)	12.8
	BEARING 204-011-110-3	122	Excessive Wear	45.9
			Modification	22.9
			Missing	3.3
			Debris Damage (Scored, Rough)	3.3
			Overheat Pitting (Mechanical Damage)	24.6

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	BEARING 204-011-111-1	124	Excessive Wear	41.9
			Fatigue Failure (Broken, Mutilated)	6.4
			Surface Compressive Failure (Pitting)	3.2
			Debris Damage (Rough)	4.8
			Overheat Pitting (Mechanical Damage)	43.5
	BEARING 204-011-112-1	118	Excessive Wear	42.4
			Fatigue Failure (Broken)	5.1
			Surface Compressive Failure (Pitting)	3.4
			Debris Damage (Rough)	5.1
			Overheat Pitting (Mechanical Damage)	44.0

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	PITCH HORN ASSEMBLY 204-011-120-5	20	Corrosion Pitting (Pitting)	80.0
			Missing	10.0
			Loss of Torque (Mechanical Damage)	10.0
	GRIP ASSEMBLY 204-011-121-5	40	Corrosion Pitting (Pitting)	87.5
			Unknown (Unknown, Condemned)	12.5
	BEARING HOUSING LINER 204-011-130-1	39	Corrosion Pitting (Pitting)	46.1
			Unknown	2.6
			Debris Damage (Gouged, Scored, Galled)	30.8
			Pitting Erosion (Mechanical Damage)	20.5
	CLEVIS 204-011-142-3	42	Corrosion Pitting (Pitting)	97.6

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Loss of Torque (Mechanical Damage)	2.4
	THREADED END ROD 204-011-143-1	45	Corrosion Pitting (Pitting)	97.8
			Damaged Threads (Mechanical Damage)	2.2
	ROD END CLEVIS 204-011-179-1	2	Corrosion Pitting (Pitting)	100.0
MAIN ROTOR HUB ASSEMBLY 540-011-101-5 (32 Assemblies Reviewed)	HOUSING ASSEMBLY 540-011-106-5	10	Corrosion Pitting (Pitting)	20.0
			Corrosion	20.0
			Missing	40.0
			Erroneous	20.0
	BEARING 540-011-110-9	45	Excessive Wear	40.0
			Missing	22.2
			Torn (Torn, Cut, Mutilated)	24.4

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Overheat Erosion (Mechanical Damage)	13.3
	SLEEVE BEARING 540-011-110-11	43	Excessive Wear	37.2
			Missing	20.9
			Torn (Torn, Mutilated)	18.6
			Overheat Erosion (Mechanical Damage)	23.3
	CLEVIS 540-011-117-1	17	Corrosion Pitting (Pitting)	41.2
			Missing	58.8
	CLEVIS ROD END 540-011-117-3	15	Corrosion Pitting (Pitting)	33.3
			Missing	66.7
	BARREL ASSEMBLY 540-011-118-1	22	Corrosion Pitting (Pitting)	63.6

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Erosion (Scored)	4.5
			Missing	22.7
			Maintenance Error (Gouged Threads, Mutilated Adjustment Nut)	9.1
	BUSHING 540-011-131-7	10	Corrosion Pitting (Pitting)	80.0
			Corrosion Erosion Pitting (Mechanical Damage)	20.0
	MAIN ROTOR TRUNNION 540-011-150-5	8	Corrosion Pitting (Pitting)	50.0
			Missing	25.0
			Erosion (Scored)	12.5
			Erosion Pitting (Mechanical Damage)	12.5

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	EXTENSION ASSEMBLY 540-011-153-15	13	Corrosion Pitting (Pitting)	7.7
			Missing	15.4
			Unknown (Unknown, Condemned)	30.8
			Erosion (Scored)	15.4
			Corrosion (Galled)	7.7
			Deterioration (Cracked)	7.7
			Erosion Corrosion Pitting (Mechanical Damage)	15.8
<u>MAIN ROTOR HUB ASSEMBLY</u> (19 Assemblies Reviewed)	SLEEVE BEARING 540-011-110-9	30	Excessive Wear	40.0
			Missing	46.6
			Overheat (Distorted)	6.7
			Overheat Erosion (Mechanical Damage)	6.7

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	SLEEVE BEARING 540-011-110-11	26	Excessive Wear	38.4
			Missing	30.8
			Overheat (Distorted)	15.4
			Overheat Erosion (Mechanical Damage)	15.4
	SLEEVE BEARING 540-011-110-13	36	Excessive Wear	50.0
			Missing	22.2
			Overheat (Distorted)	5.5
			Torn (Torn, Mutilated)	16.7
			Overheat Erosion (Mechanical Damage)	5.5
	CLEVIS 540-011-117-2	2	Corrosion Pitting (Pitting)	100.0

TABLE 42. - Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
	SLEEVE 540-011-143-9	28	Excessive Wear	42.9
			Missing	21.4
			Overheat Pitting Erosion (Mechanical Damage)	35.7
	SLEEVE 540-011-143-11	25	Excessive Wear	28.0
			Missing	24.0
			Overheat Erosion Pitting (Mechanical Damage)	48.0
	SLEEVE 540-011-143-13	26	Excessive Wear	30.8
			Missing	23.1
			Overheat Pitting Erosion (Mechanical Damage)	46.1
	TRUNNION 540-011-150-5	9	Corrosion Pitting (Pitting)	44.4

TABLE 42. Continued

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
			Erosion (Scored, Galled)	22.2
			Deterioration (Cracked)	11.1
			Maintenance Error (Damaged Threads)	11.1
			Corrosion Erosion Pitting (Mechanical Damage)	11.1
	BUSHING 540-011-161-3	2	Corrosion Pitting (Pitting)	100.0
SWASHPLATE AND SUPPORT ASSEMBLY 204-011-400-11 (16 Assemblies Reviewed)	TRUNNION ASSEMBLY KSP 9001	8	Corrosion Pitting (Pitting)	25.0
			Excessive Wear	37.5
			Corrosion/ERosion (Bad Seals)	37.5
	LINER 204-011-425-1	7	Corrosion Pitting (Pitting)	100.0

TABLE 42. - Concluded

Assembly	Part	Total Number Replaced	Condition Causing Replacement	Percent Replaced for Condition
SWASHPLATE AND SUPPORT ASSEMBLY 209-010-400-1	BEARING 204-011-430-1	23	Excessive Wear	13.1
(33 Assemblies Reviewed)			Corrosion Pitting (Pitting)	82.6
			Erroneous (Torn - Bearing is not Teflon)	4.3
	SUPPORT ASSEMBLY 209-010-404-1	21	Corrosion Pitting (Pitting)	14.3
			Overheat (Distorted)	9.5
			Erosion (Grooved, Nicked, Scored)	52.4
			Corrosion	4.8
			Overheat Erosion Pitting Corrosion (Mechanical Damage)	19.0

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SECTION 1. MAIN TRANSMISSION ASSEMBLY

WEIBULL HAZARD ALL INHERENT FAILURE MODES

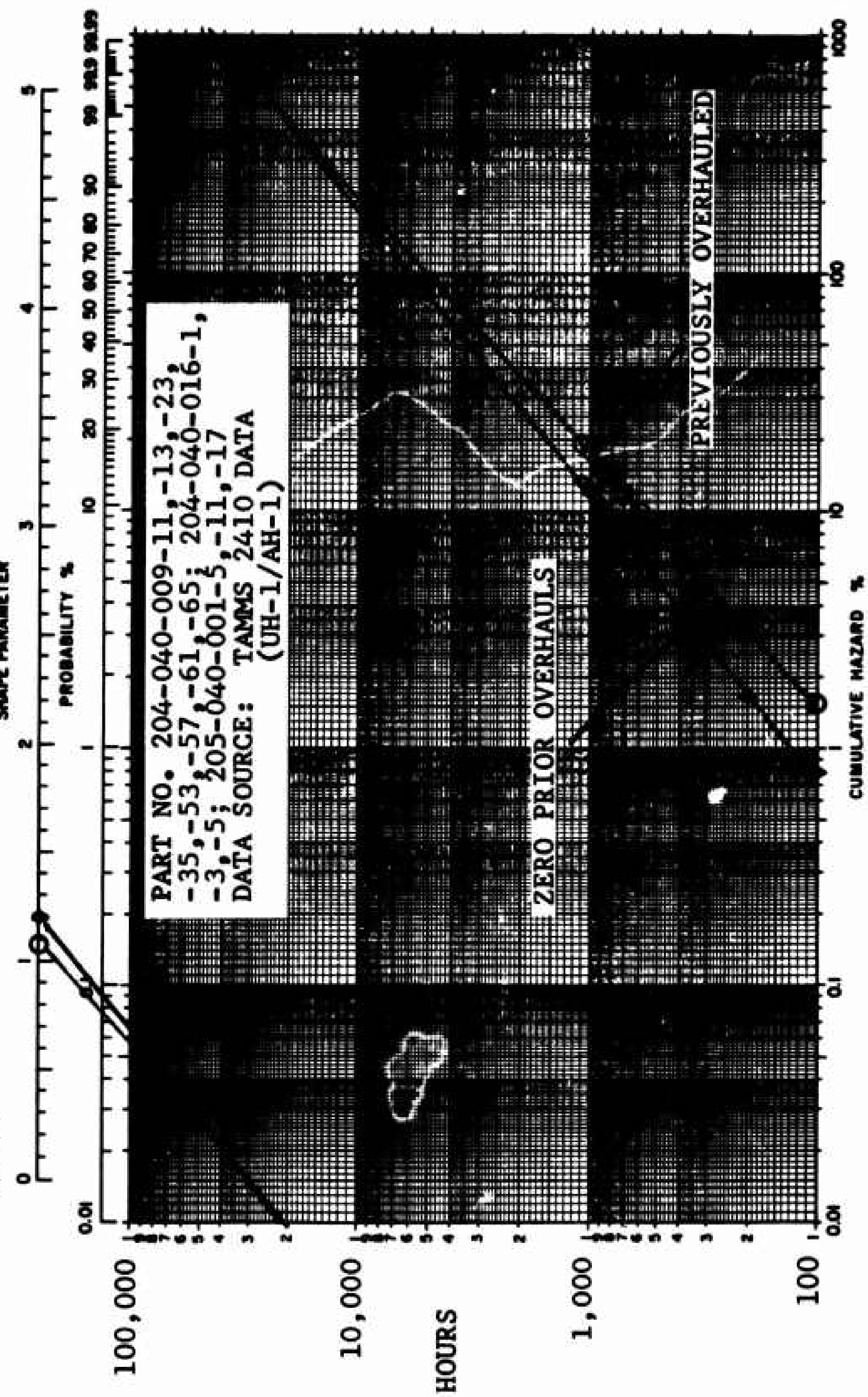


Figure A-1. Weibull hazard rate plots of main transmission.

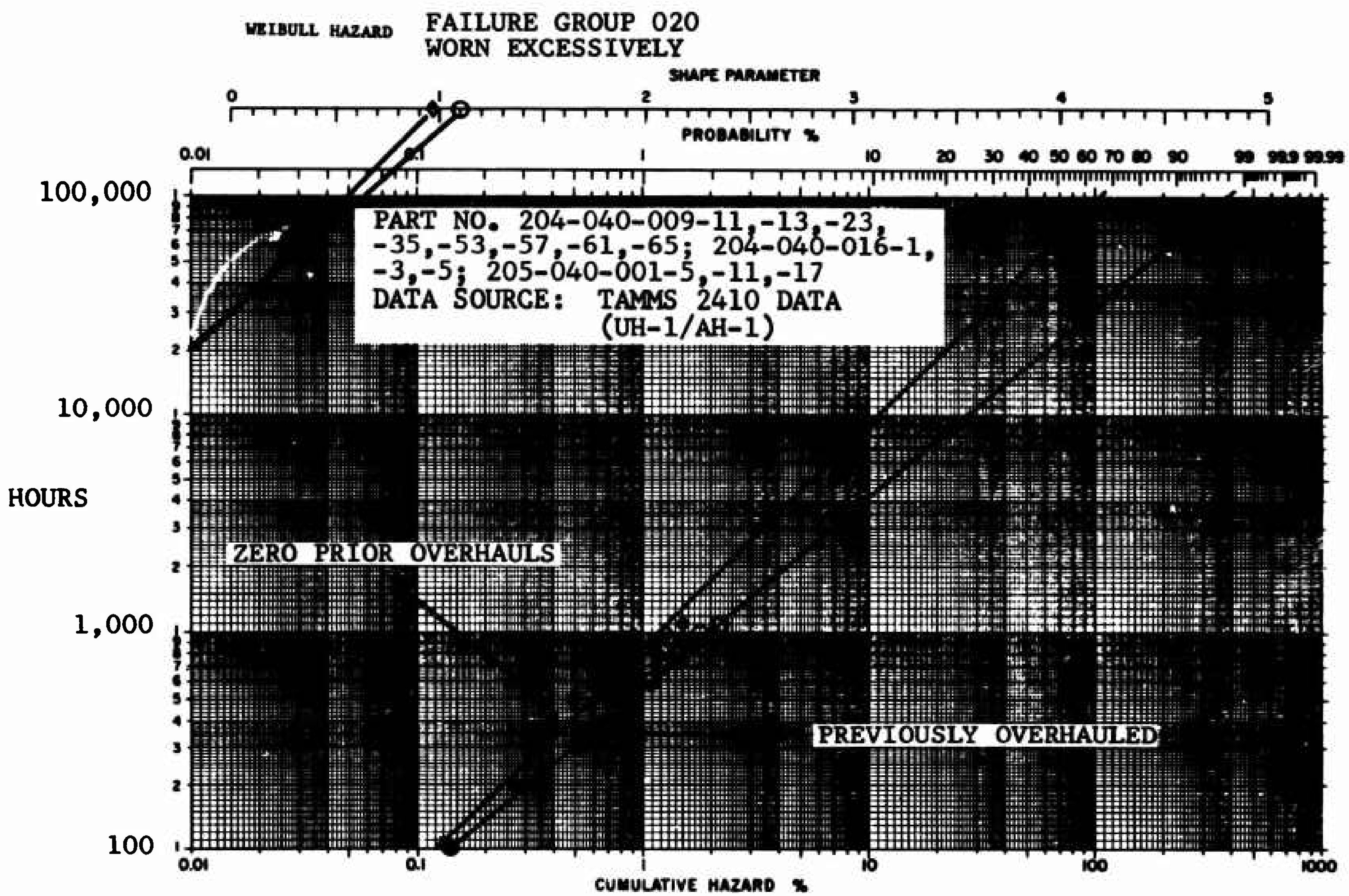


Figure A-1. Continued.

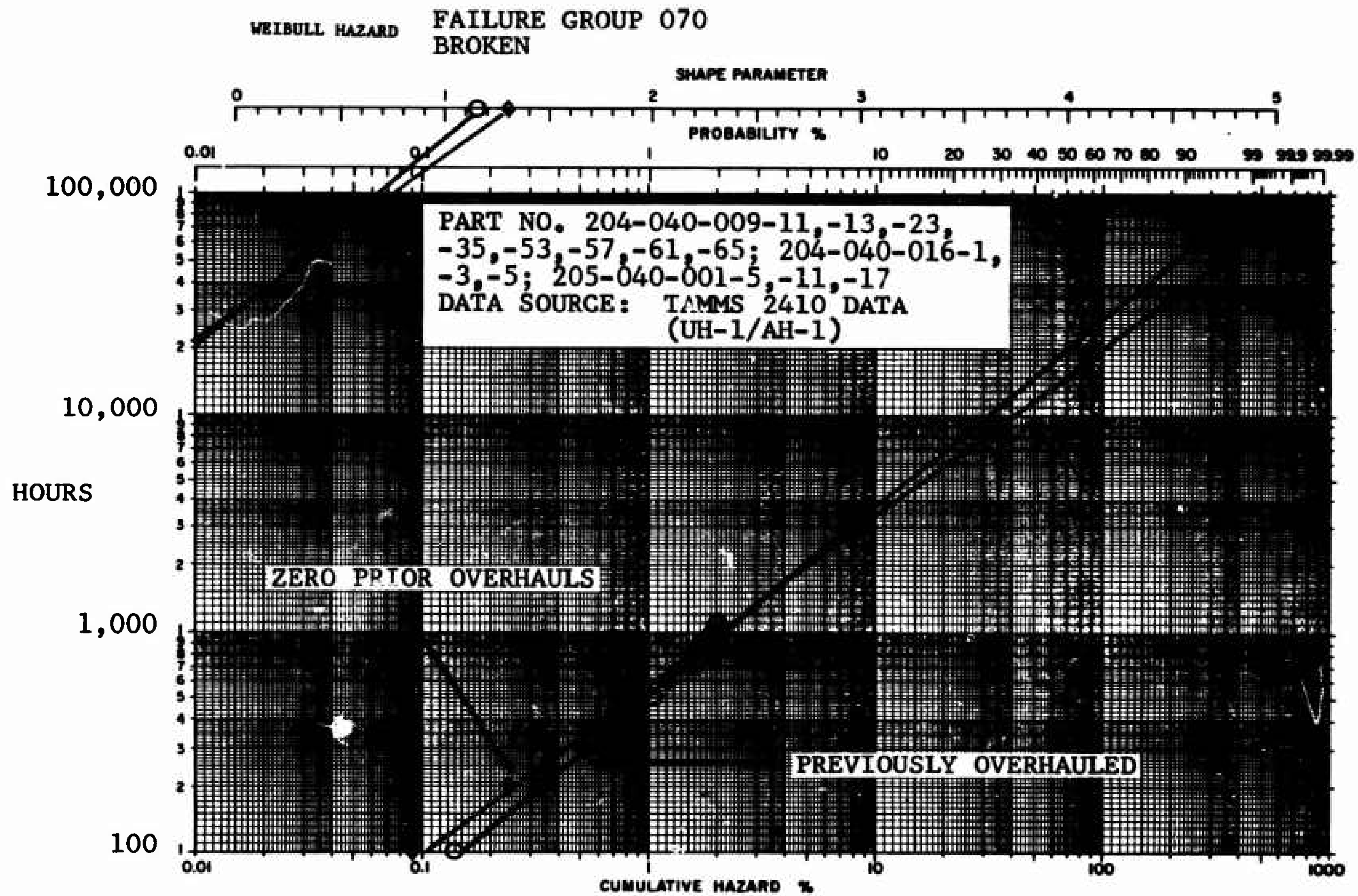


Figure A-1. Continued.

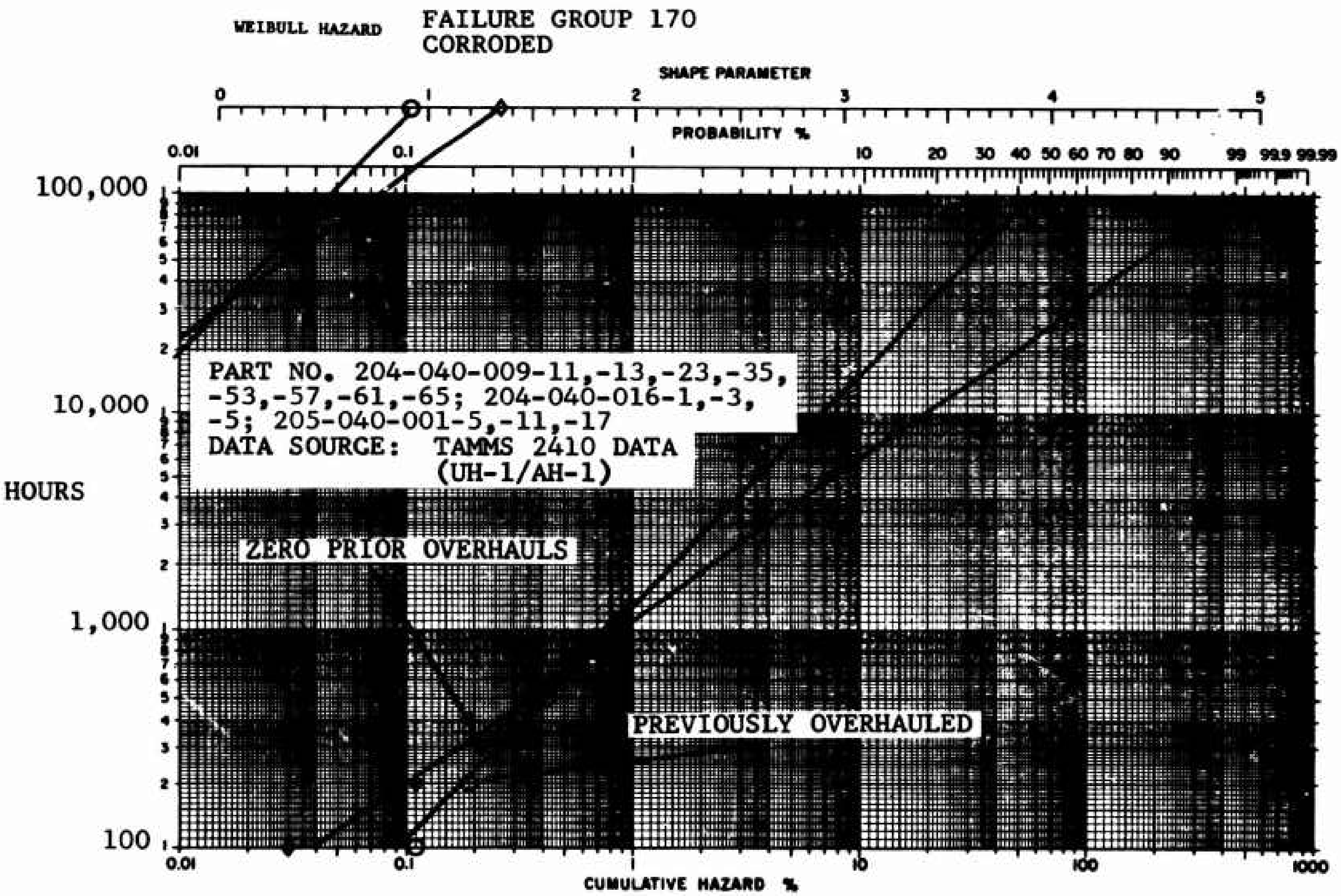


Figure A-1. Continued.

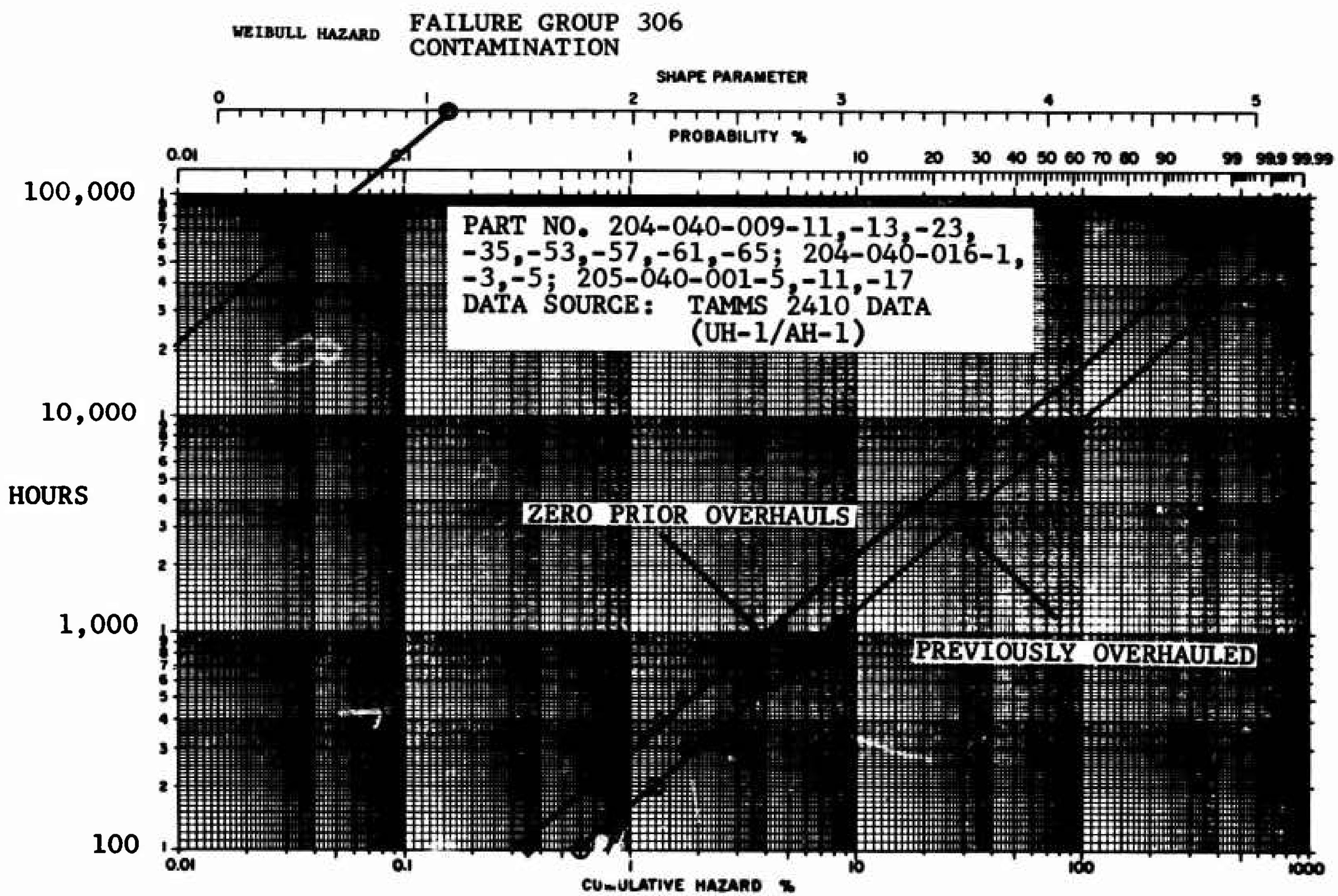
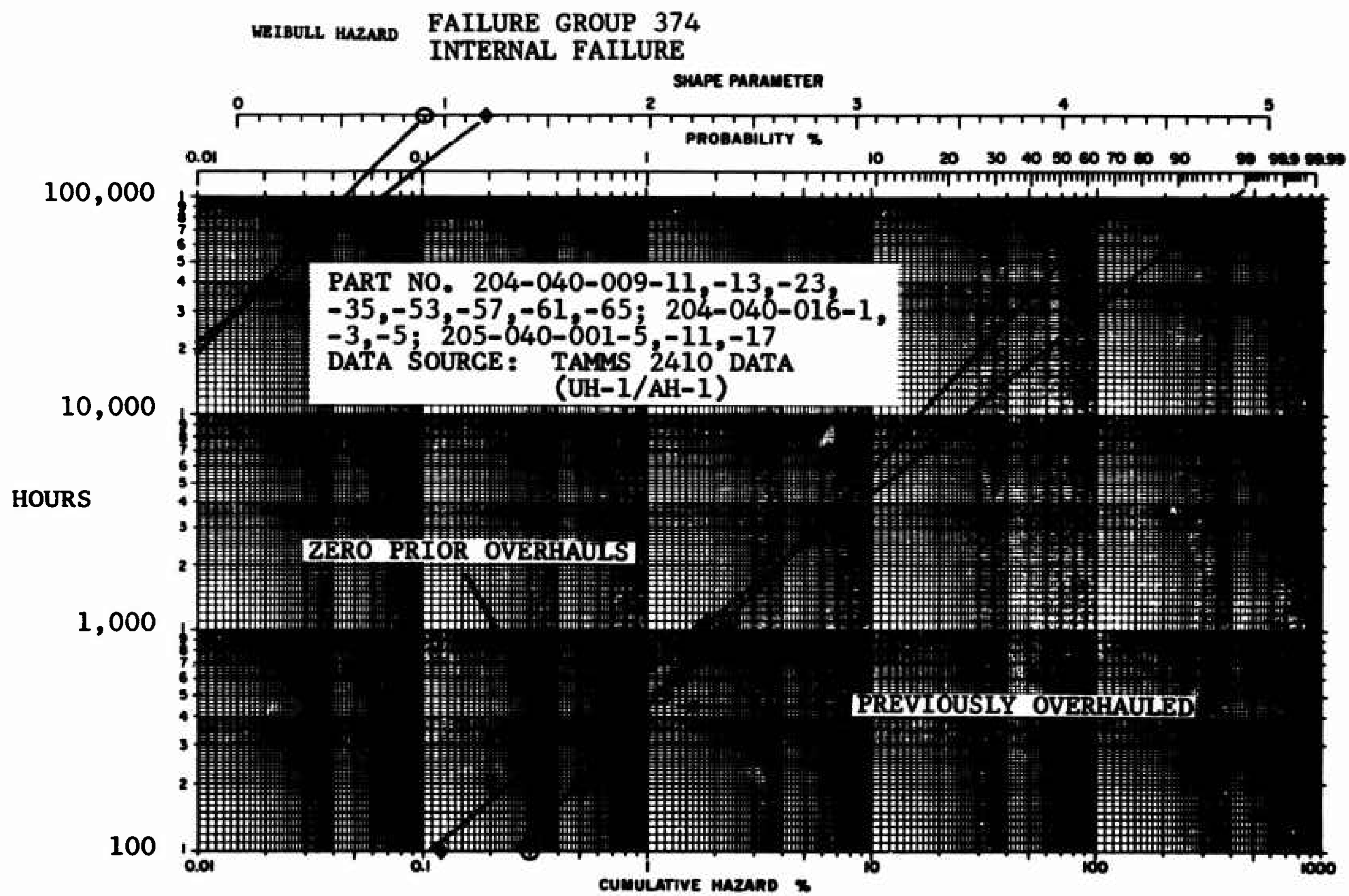


Figure A-1. Continued.



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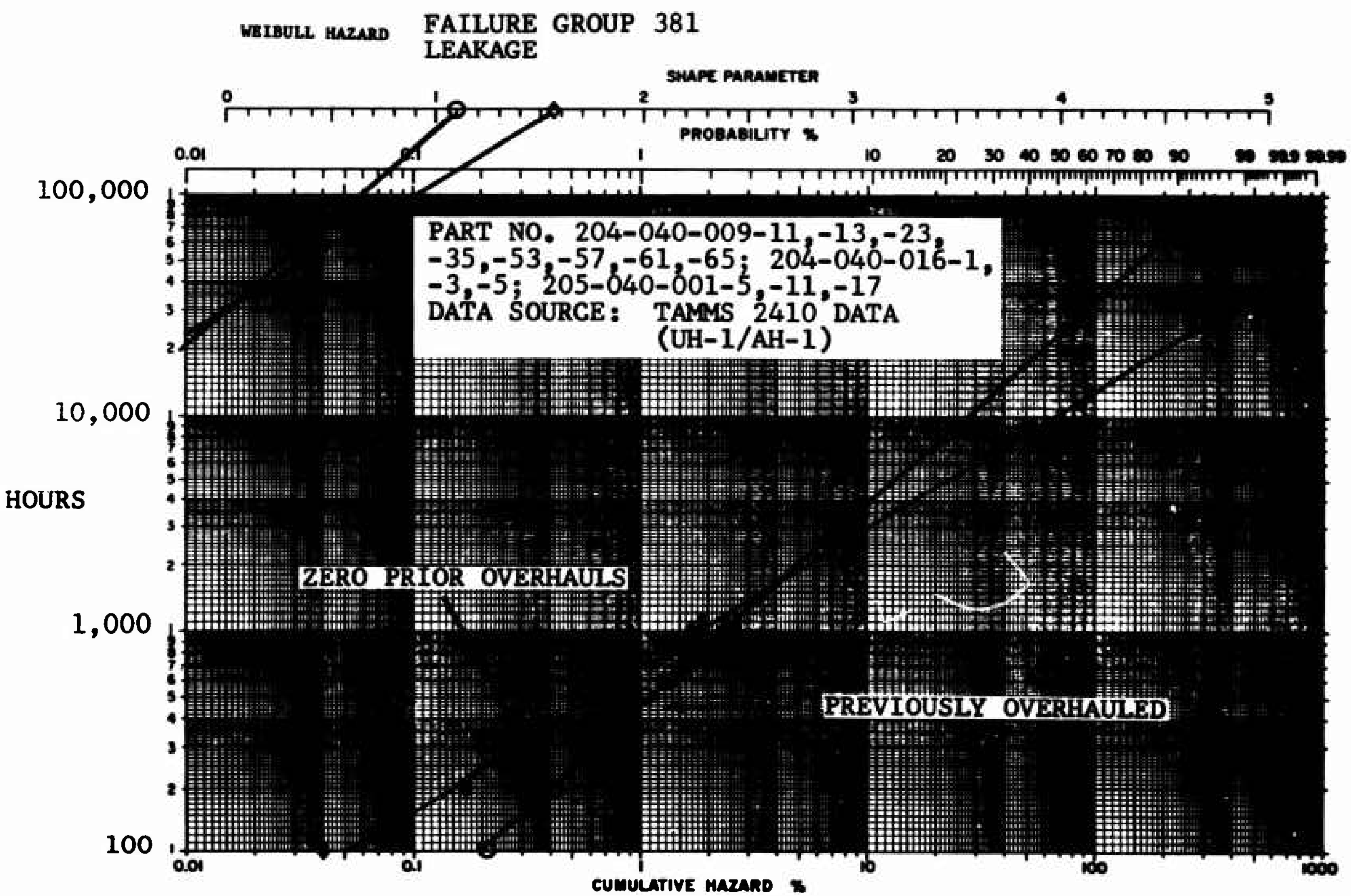

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SECTION 2. 42-DEGREE GEARBOX ASSEMBLY

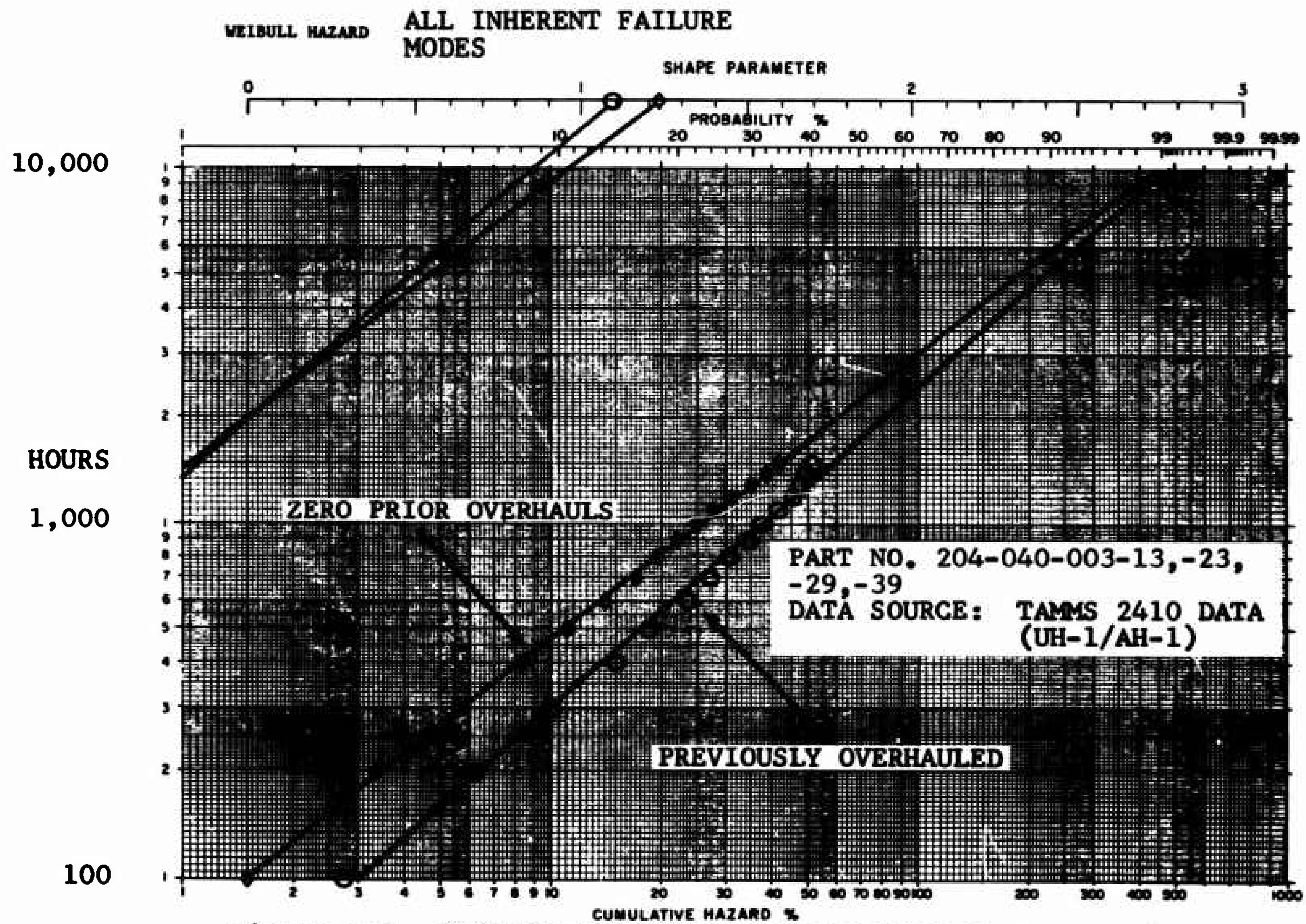
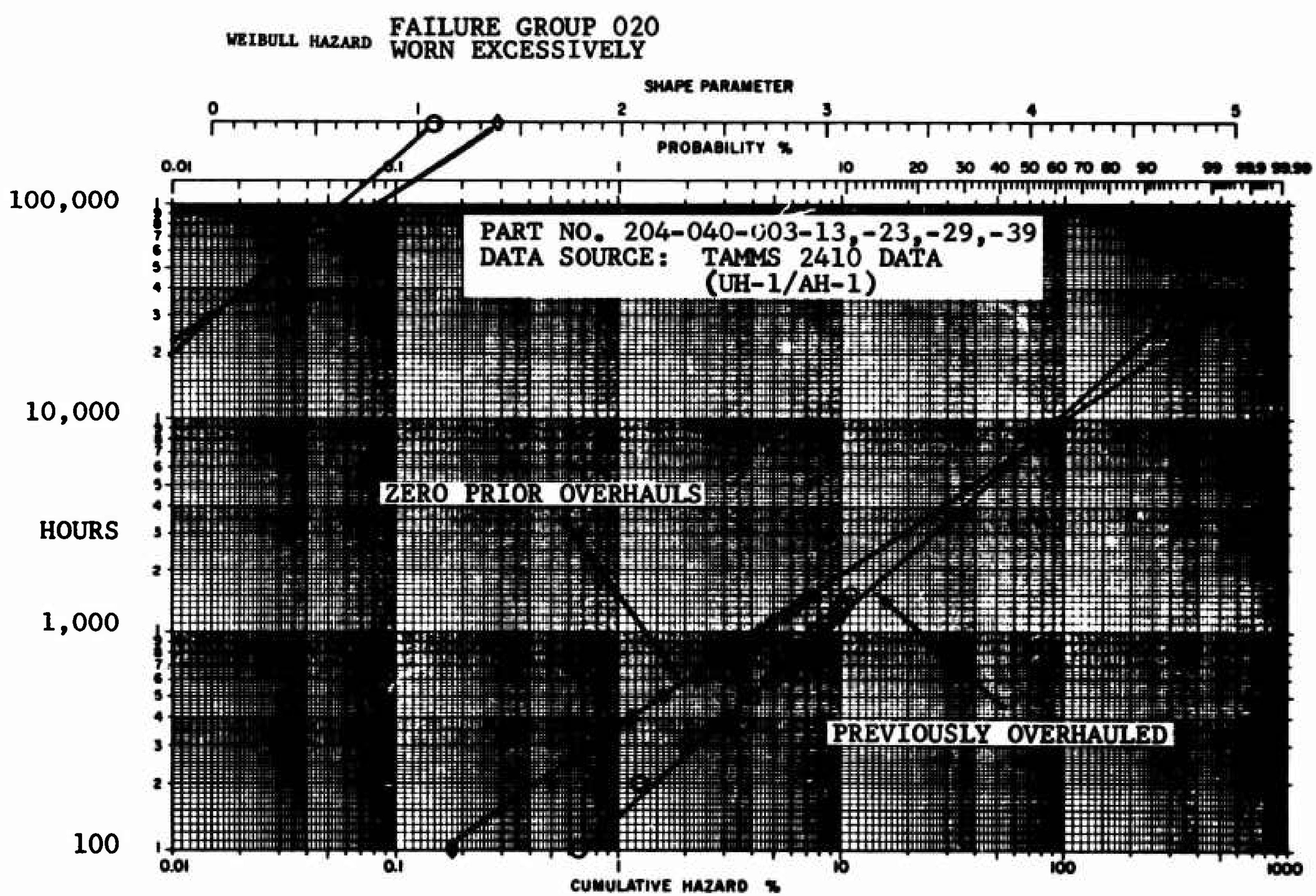


Figure A-2. Weibull hazard rate plots of 42-degree gearbox.



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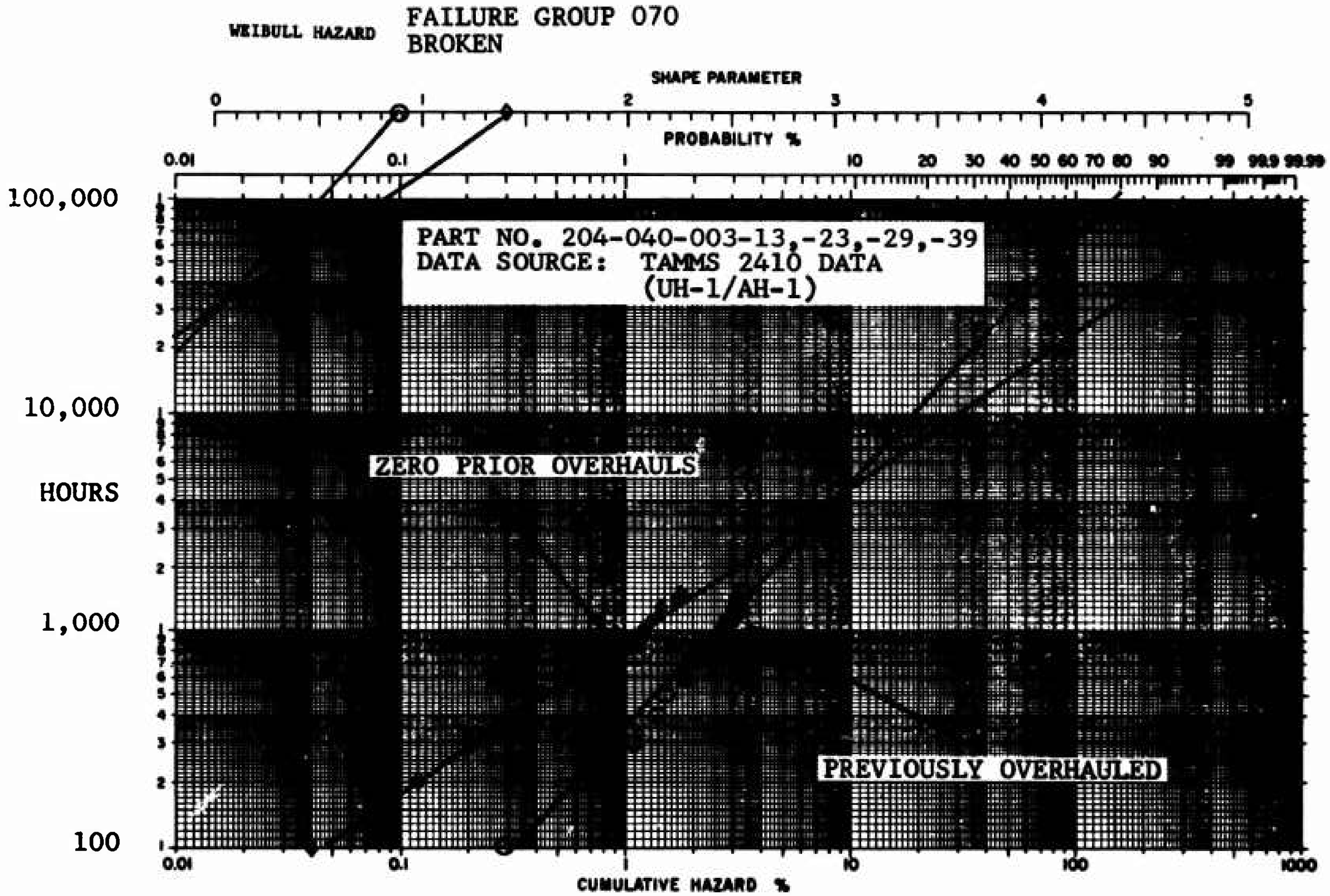

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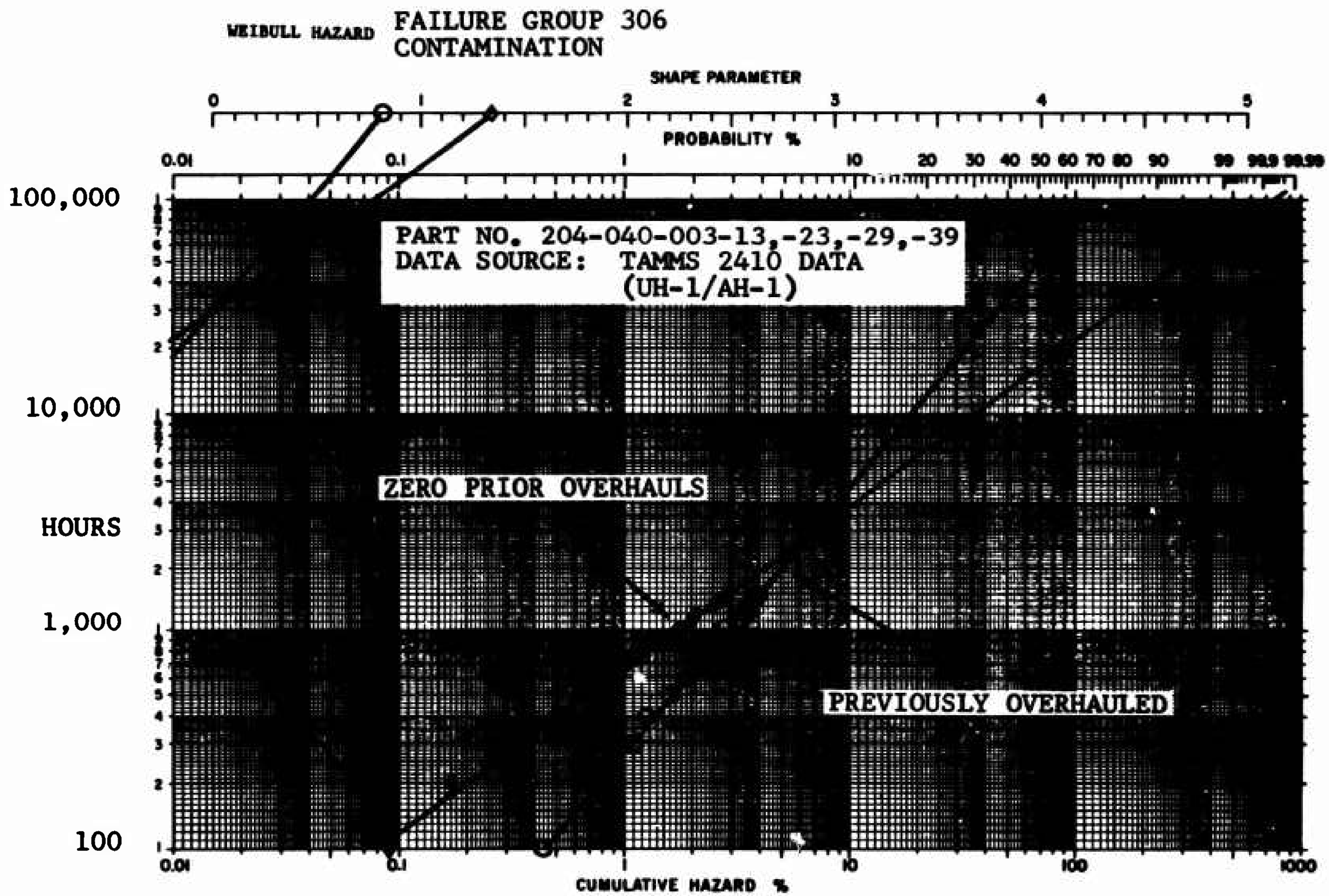

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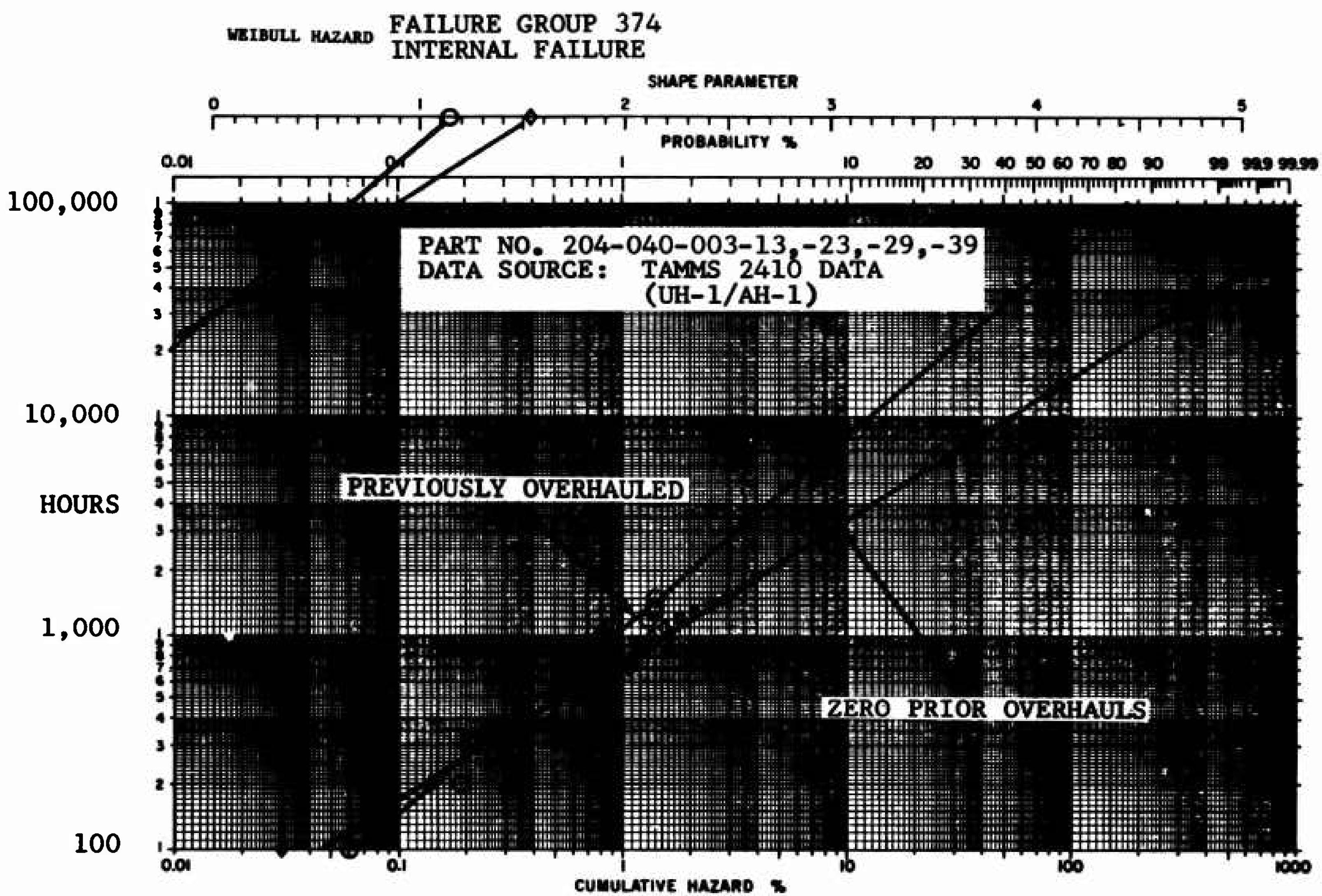

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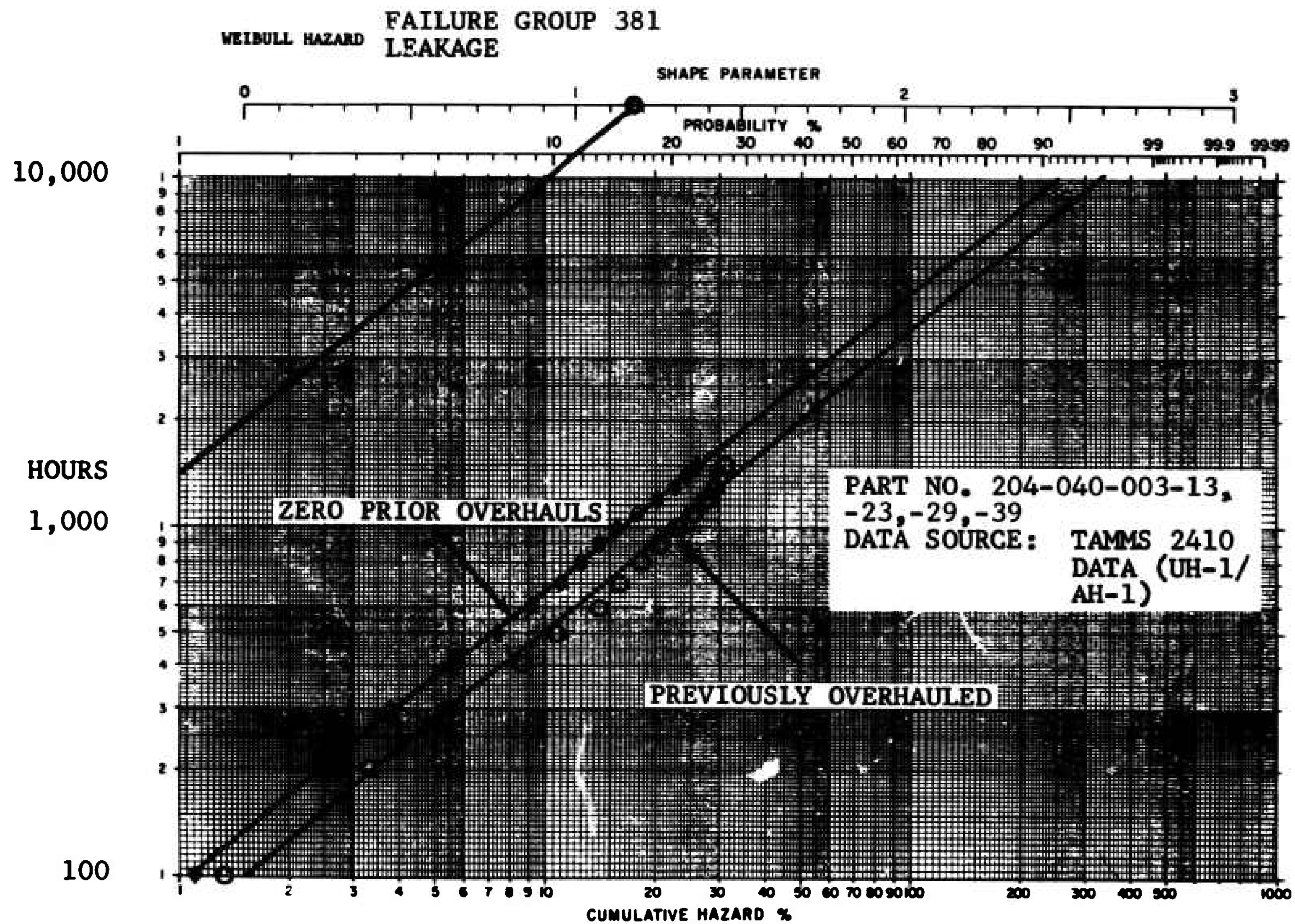

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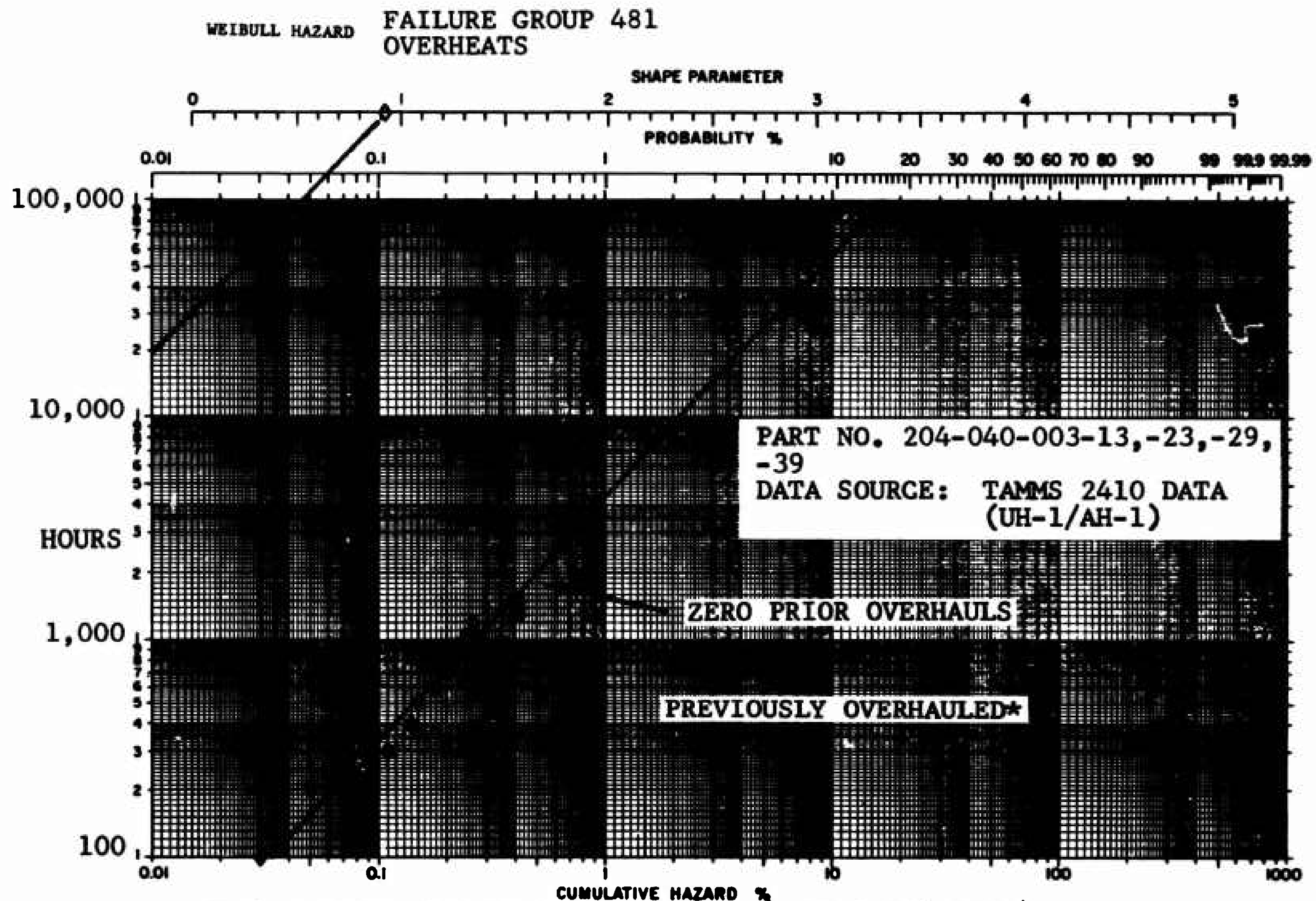


* DATA WERE INADEQUATE TO ANALYZE (FOUR ASSEMBLIES)

Figure A-2. Concluded.

SECTION 3. 90-DEGREE GEARBOX ASSEMBLY

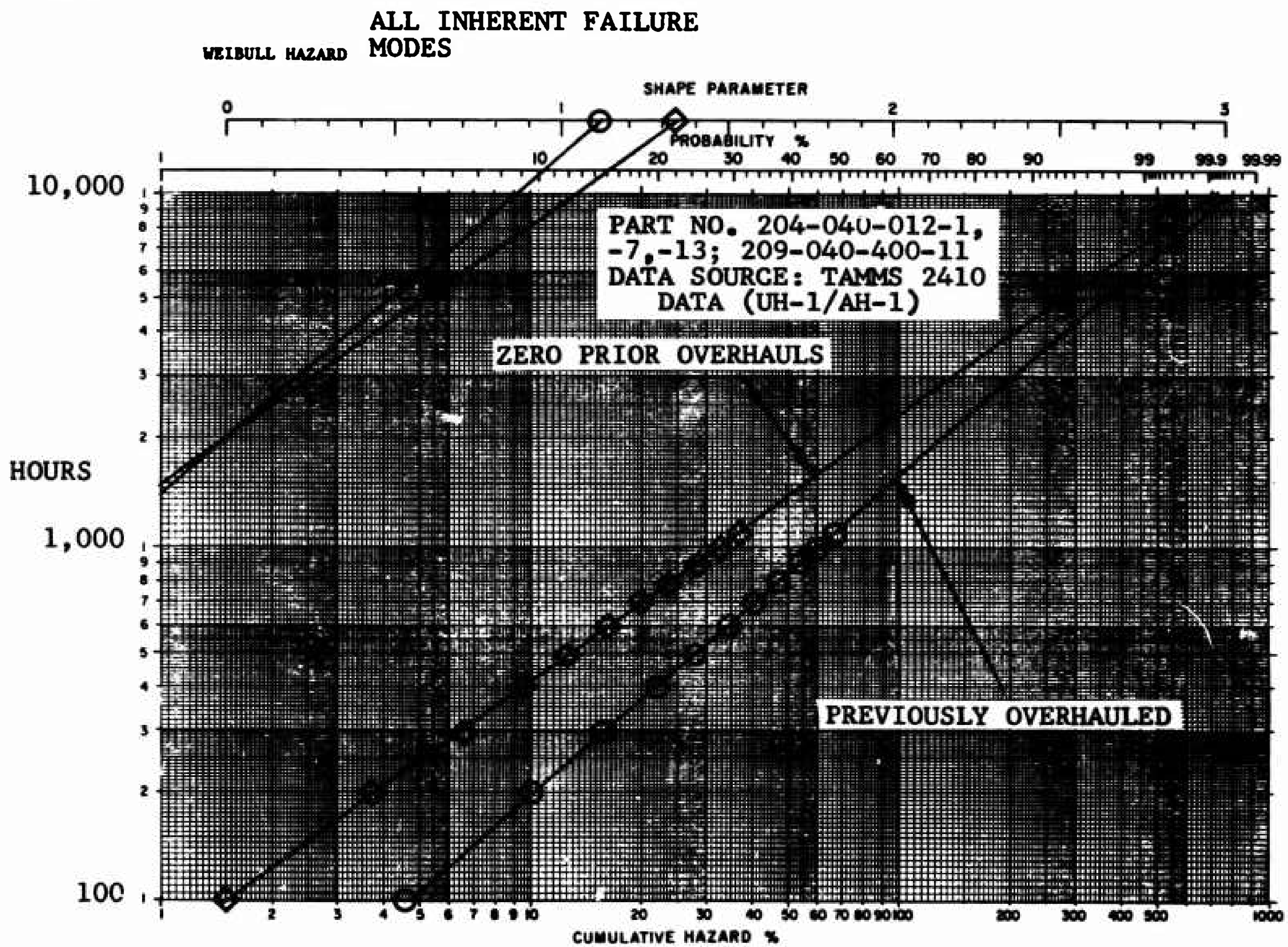
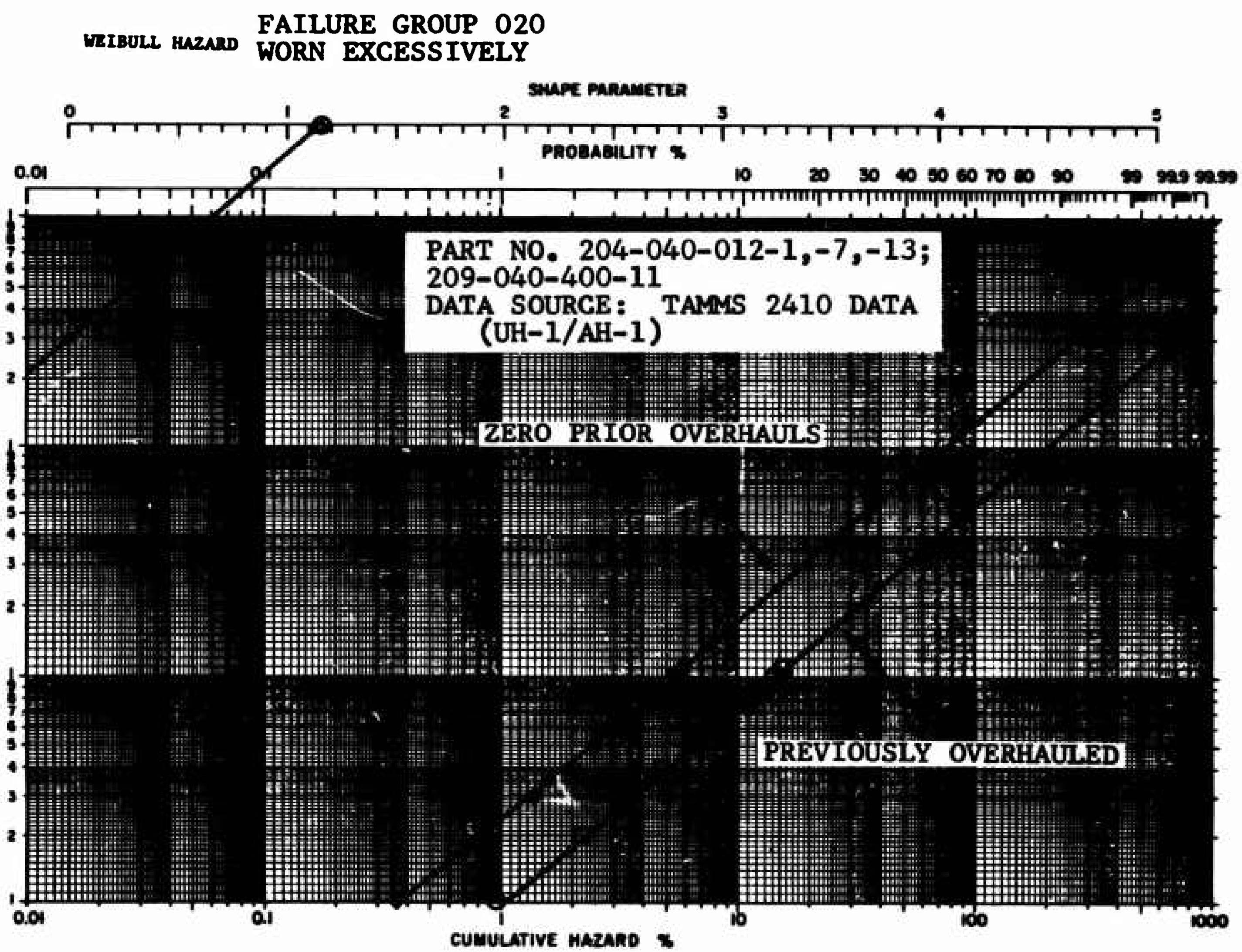


Figure A-3. Weibull hazard rate plots of 90-degree gearbox.



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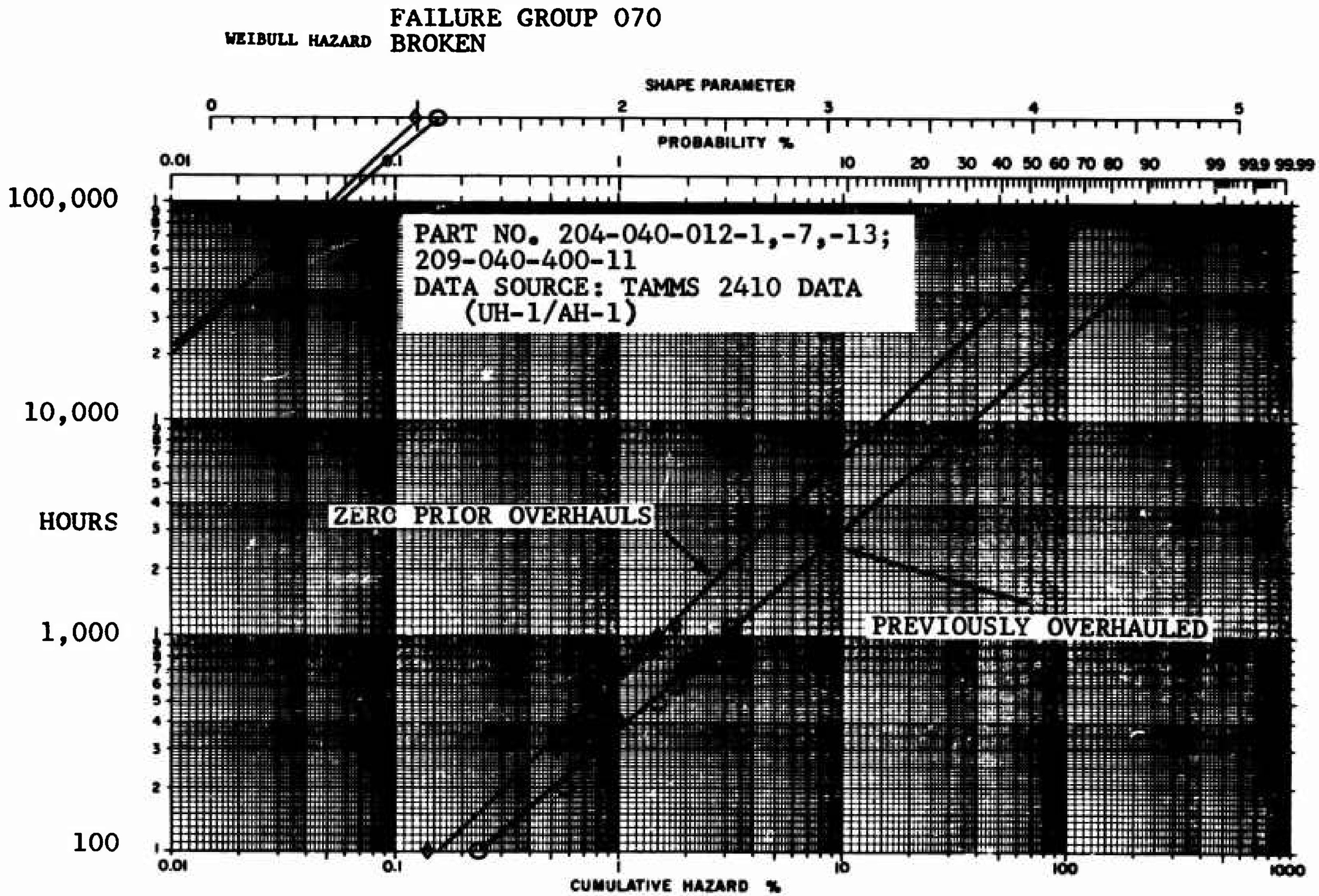

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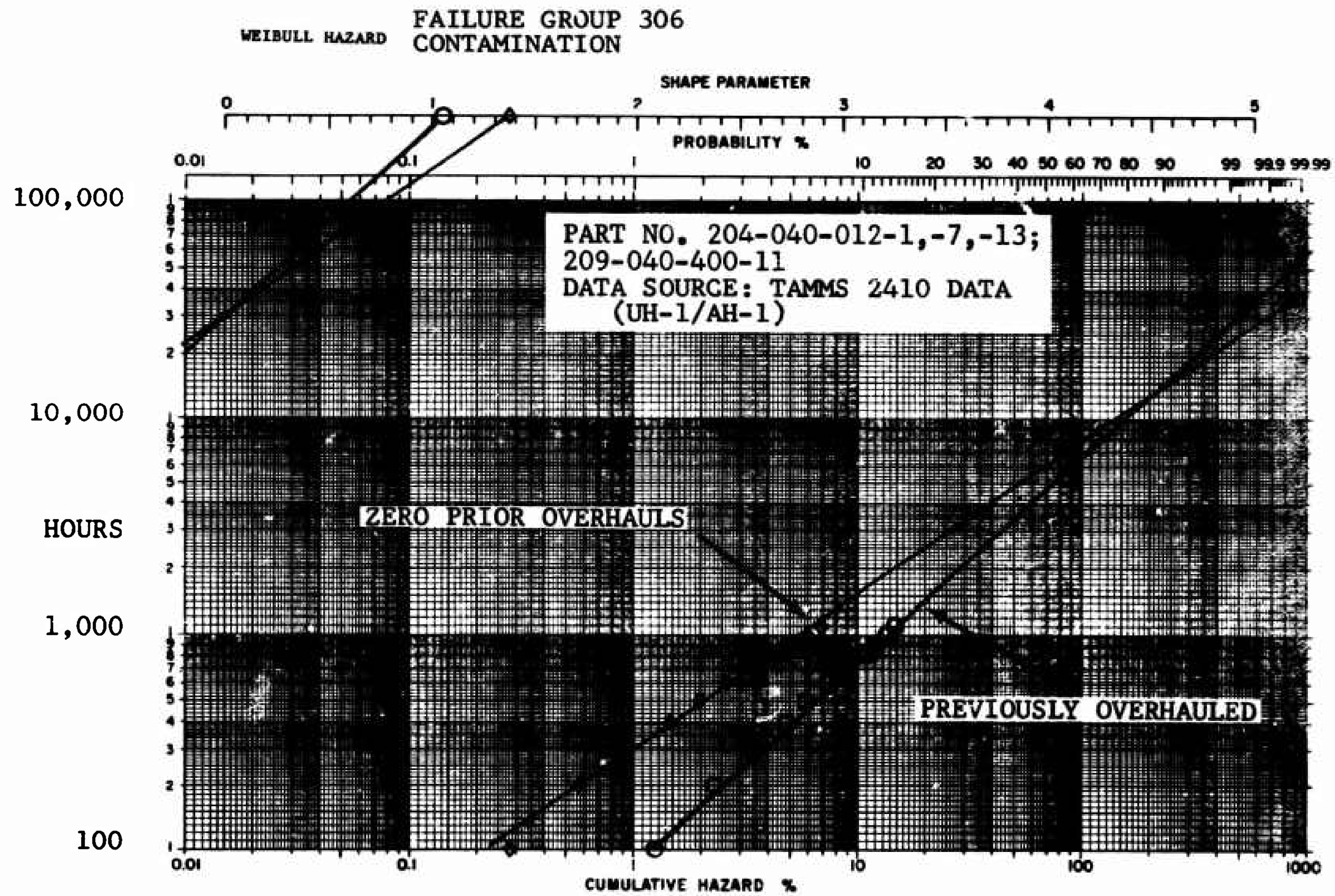

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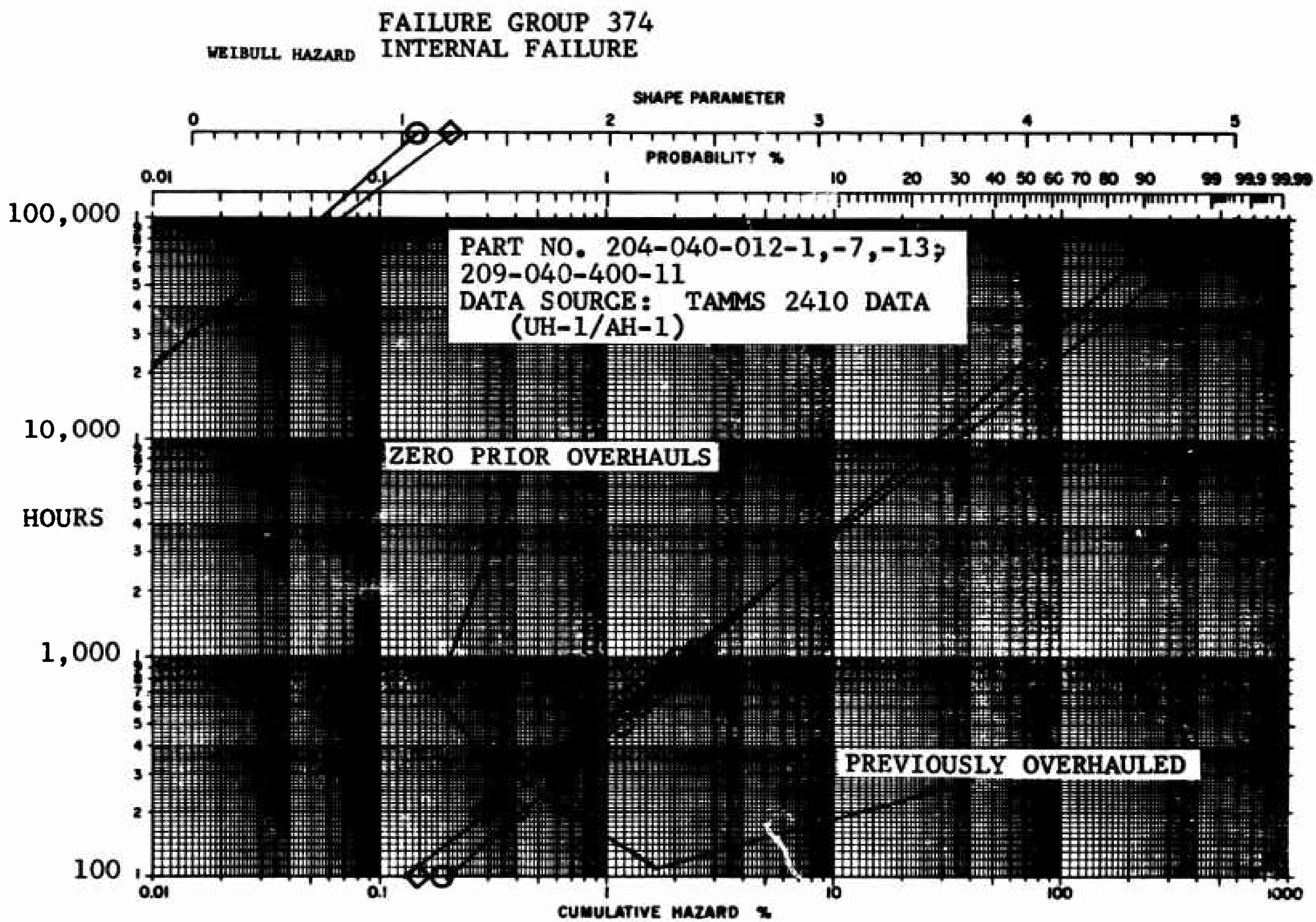

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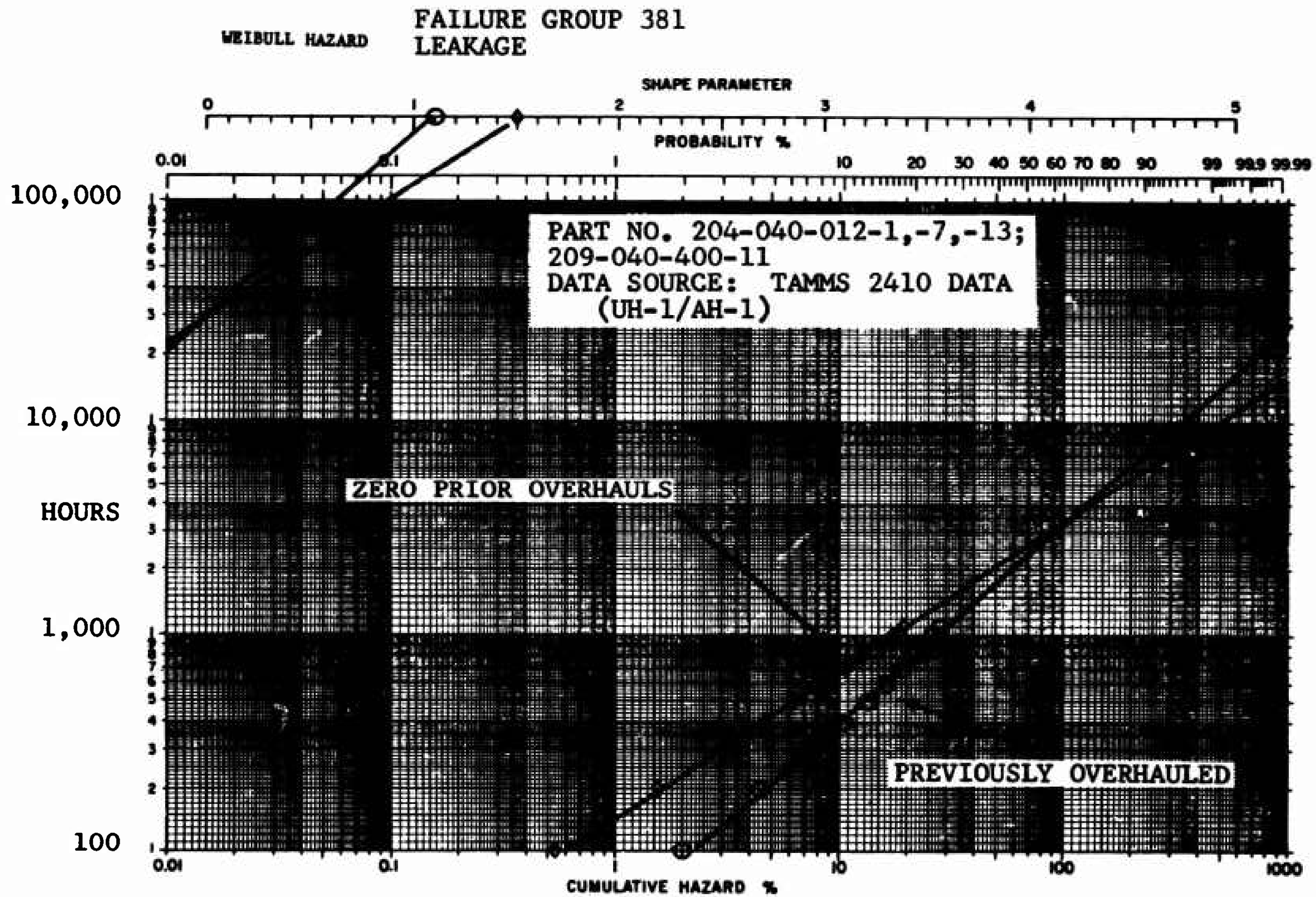


Figure A-3. Concluded.

SECTION 4. MAIN ROTOR HUB ASSEMBLY

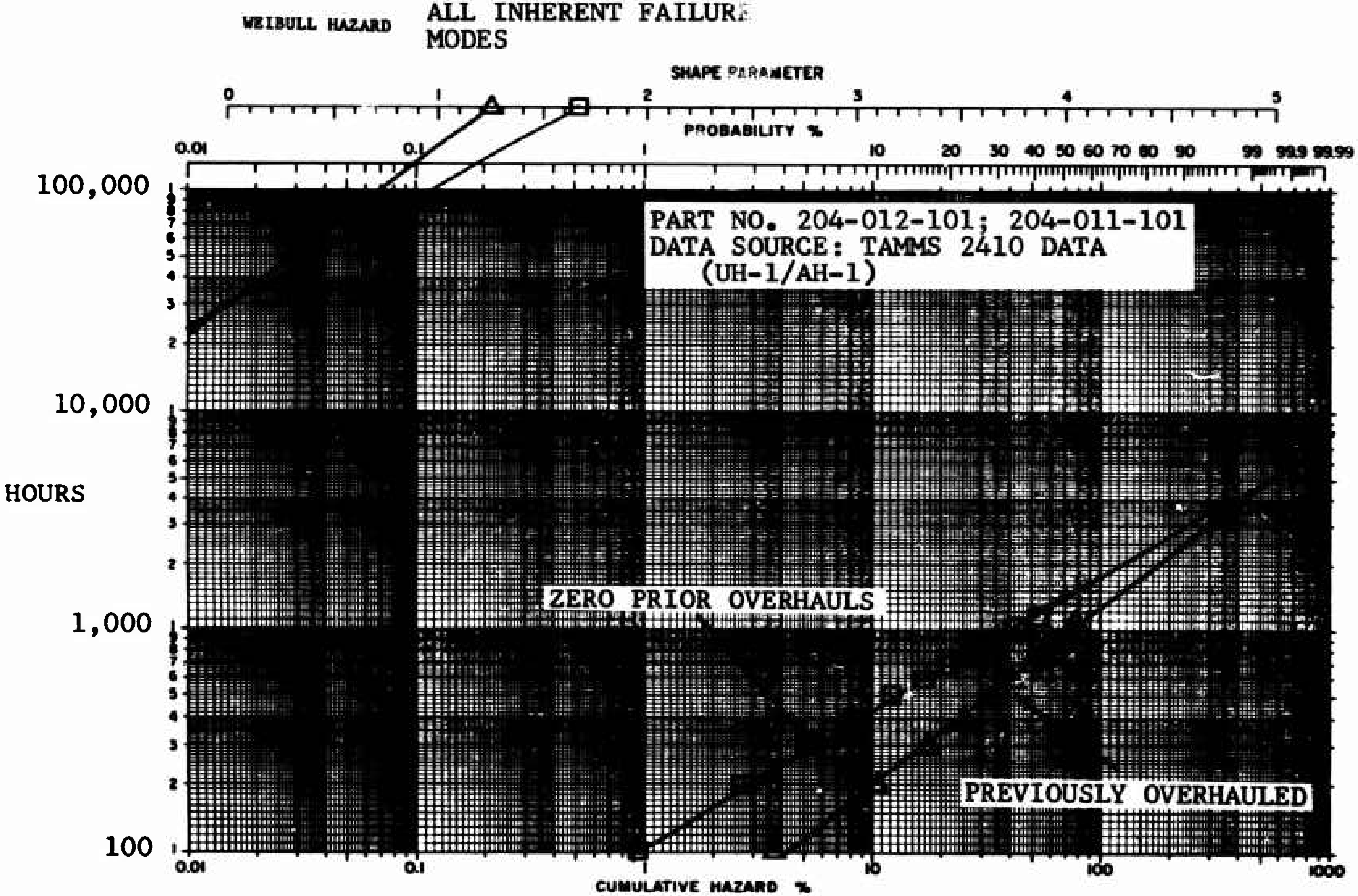
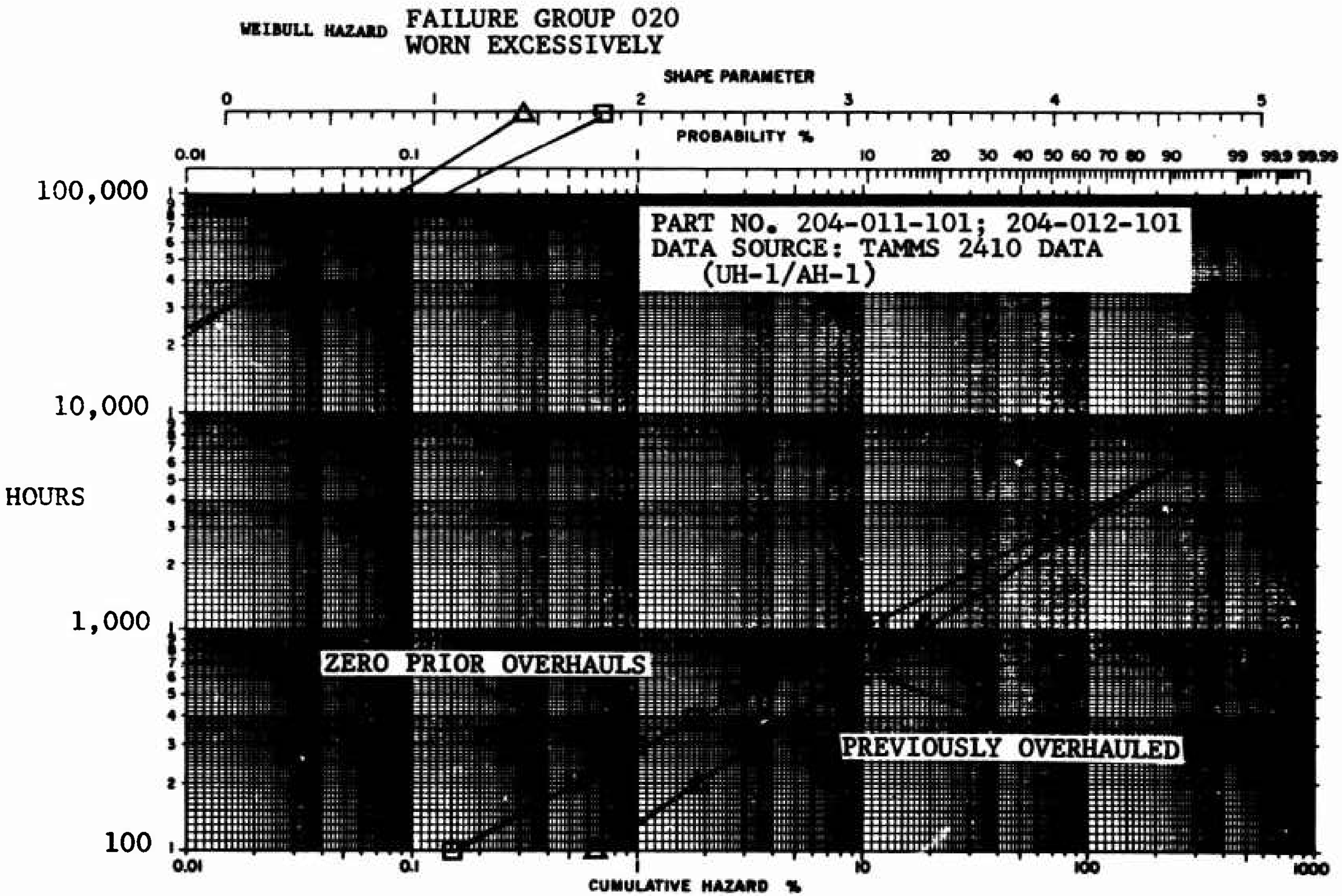


Figure A-4. Weibull hazard rate plots of UH-1B/D/H type main rotor hub.



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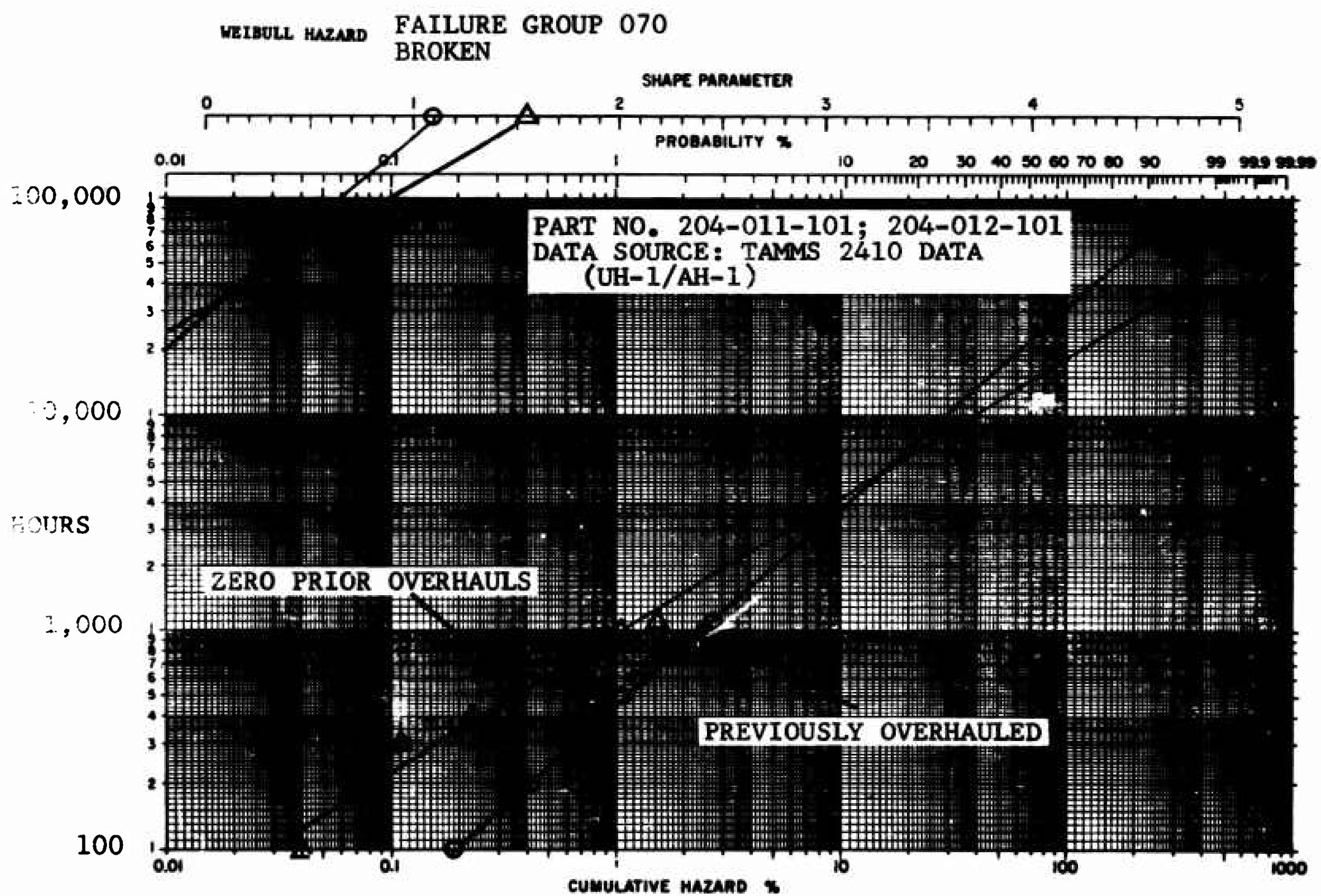

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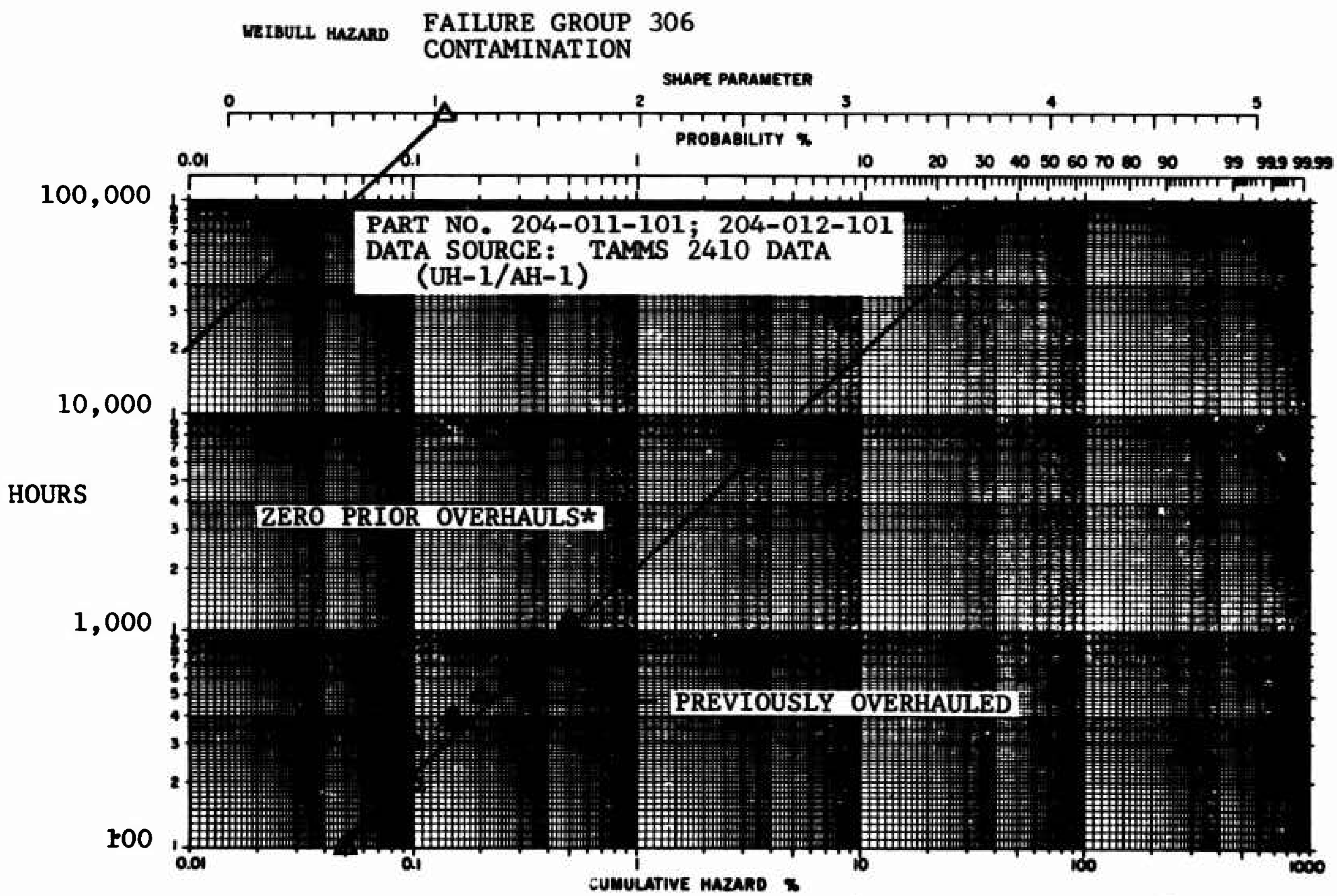
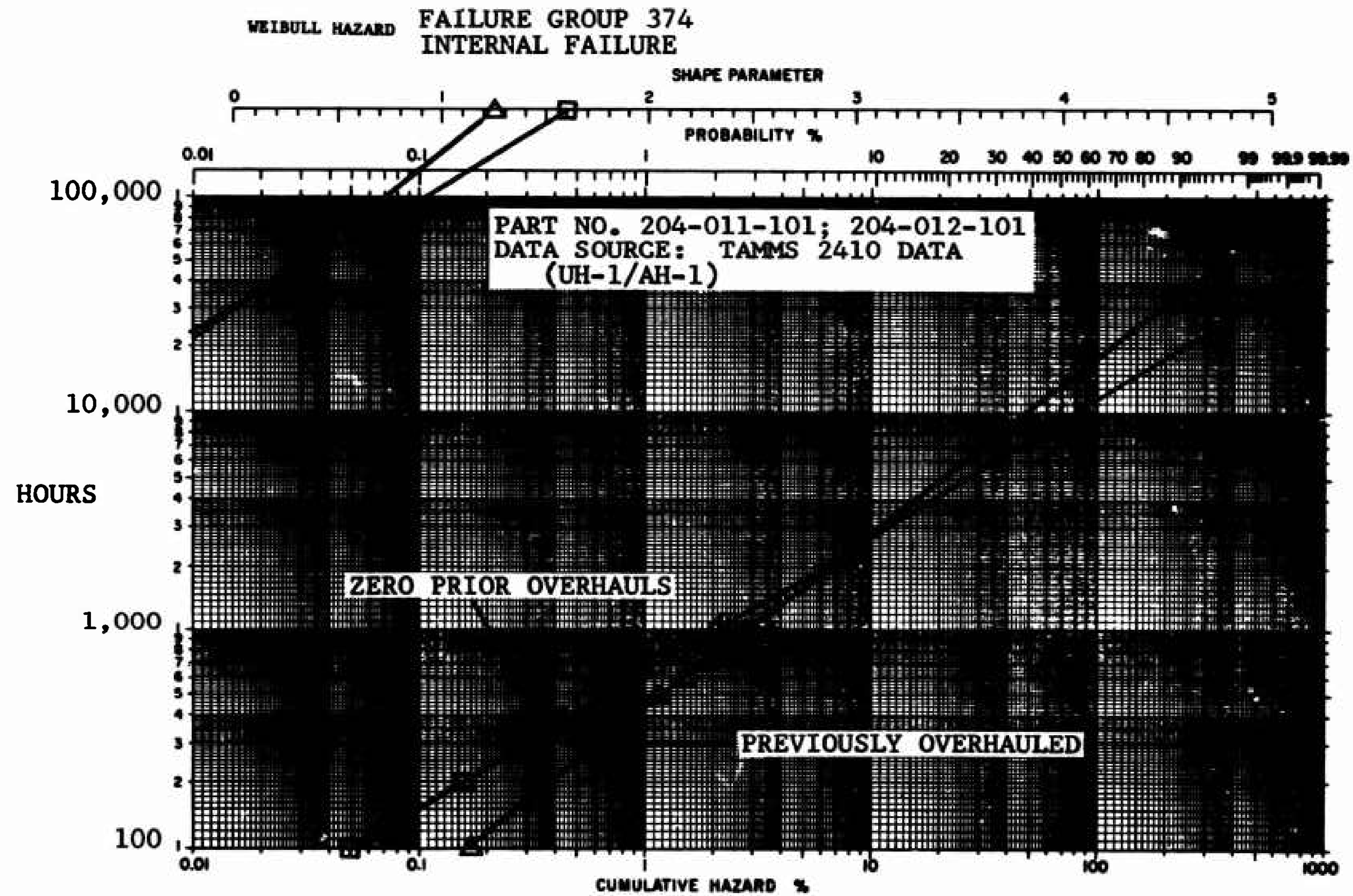


* Data were inadequate to analyze (nineteen assemblies)

Figure A-4. Continued.



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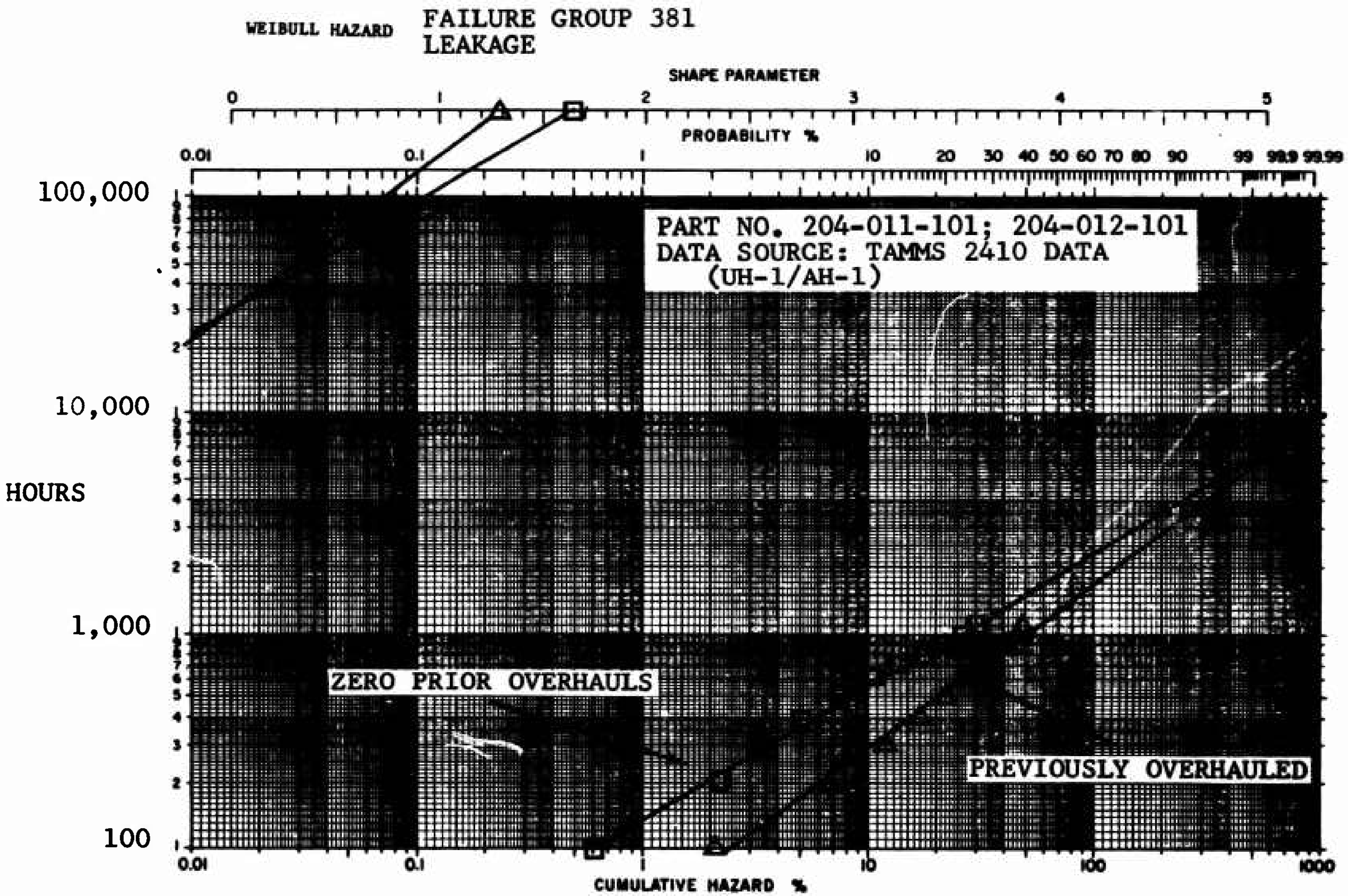

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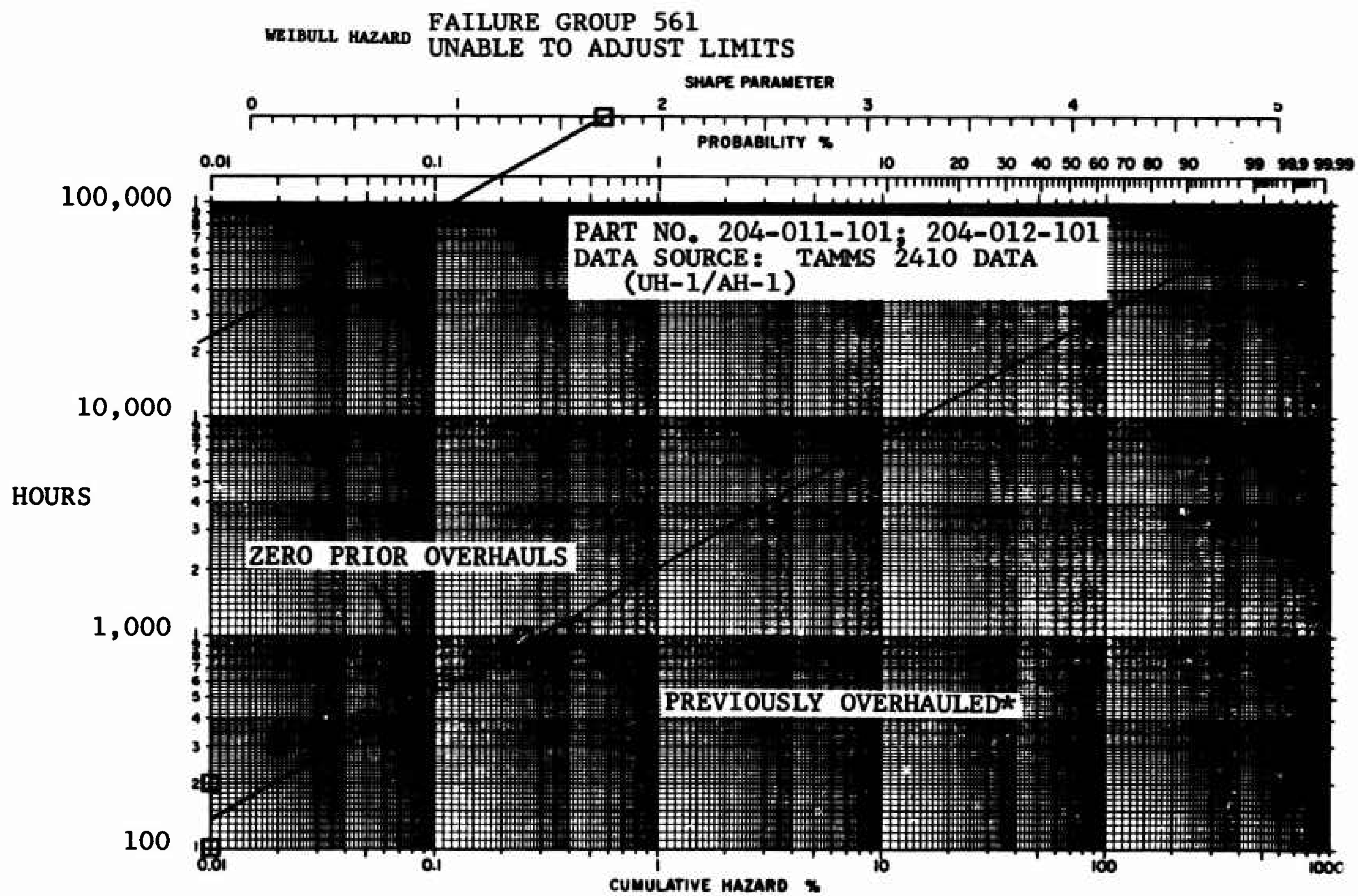
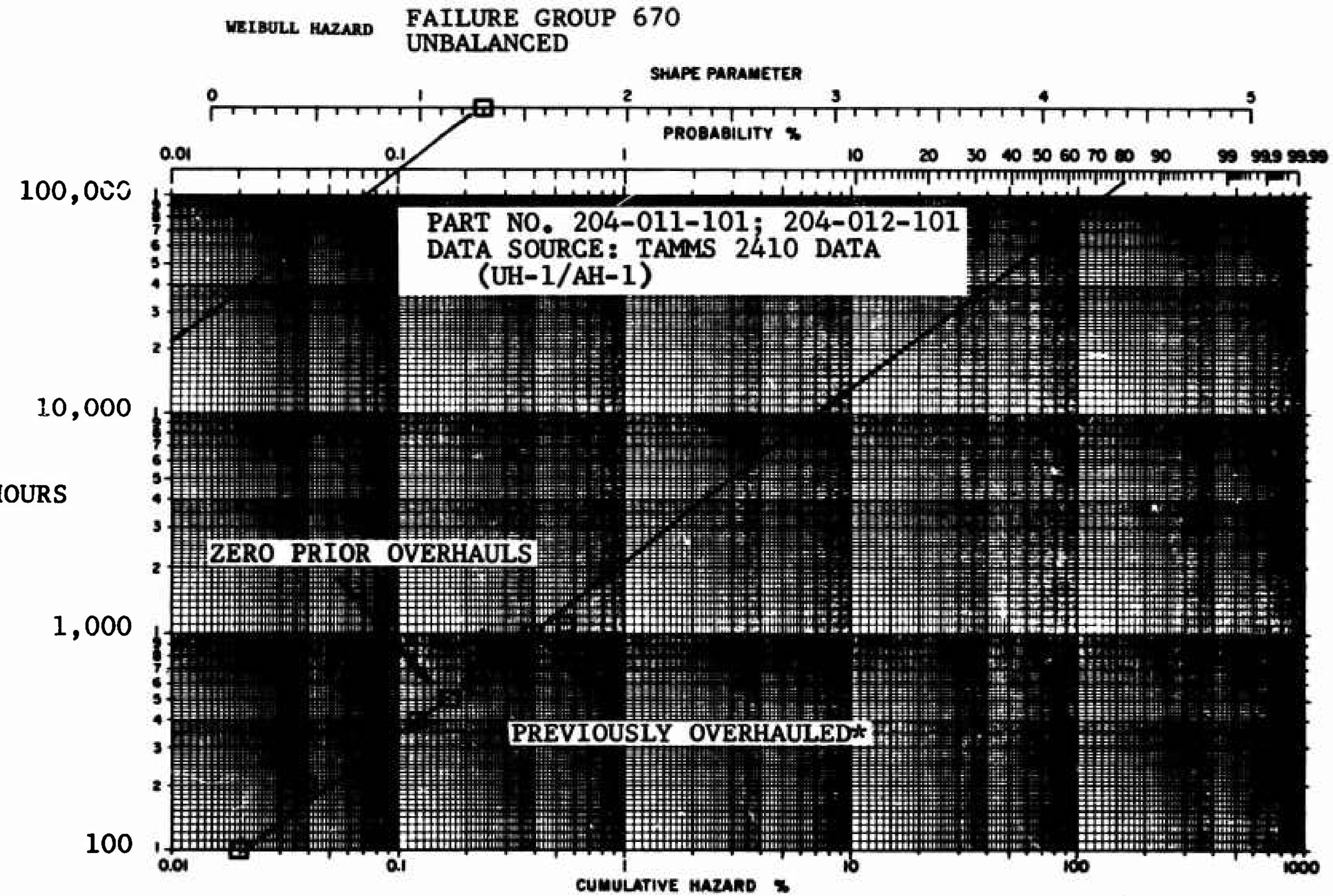


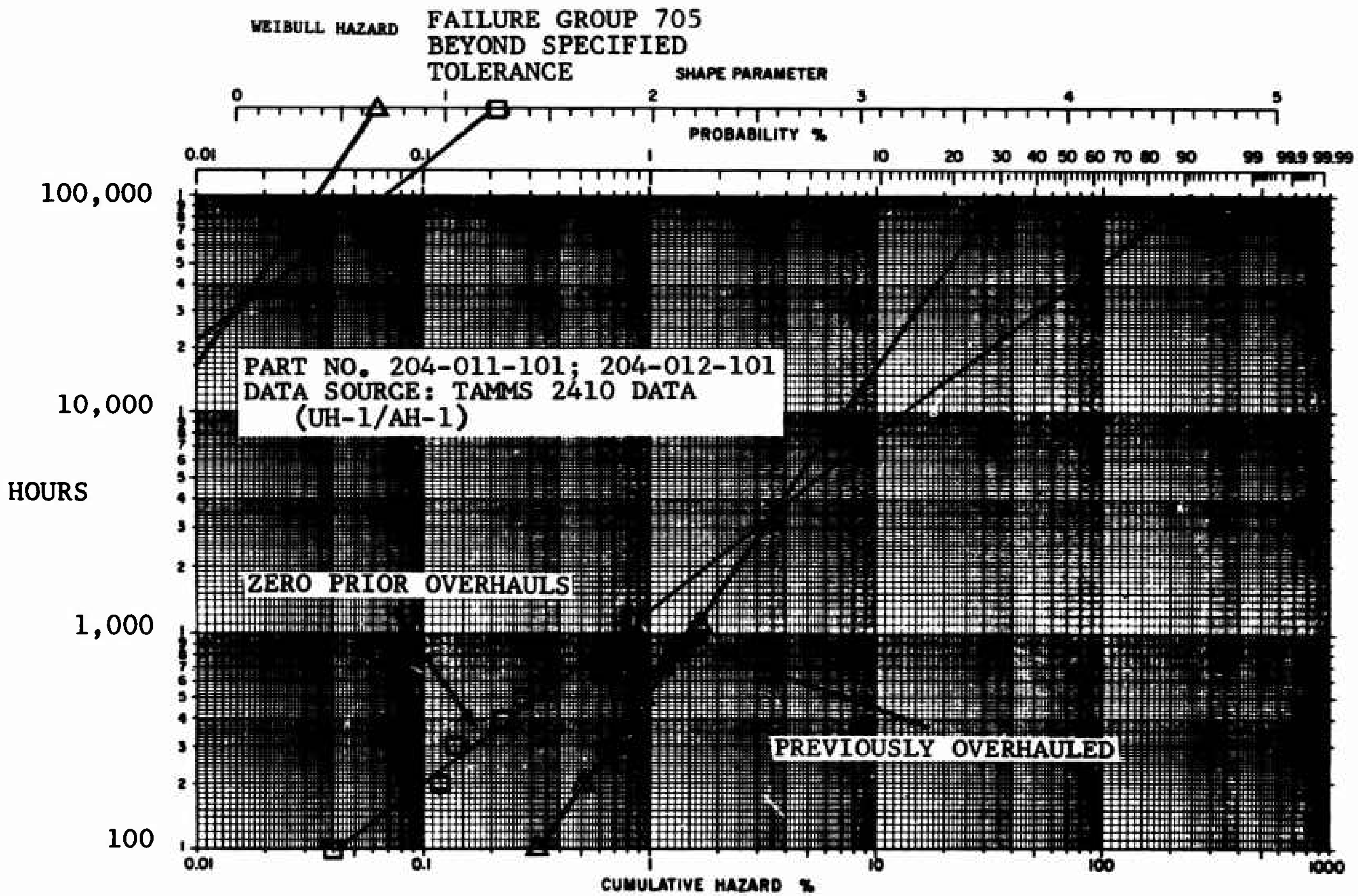
* Data were inadequate to analyze (thirteen assemblies)

Figure A-4. Continued.



* Data were inadequate to analyze (twelve assemblies)

Figure A-4. Continued.



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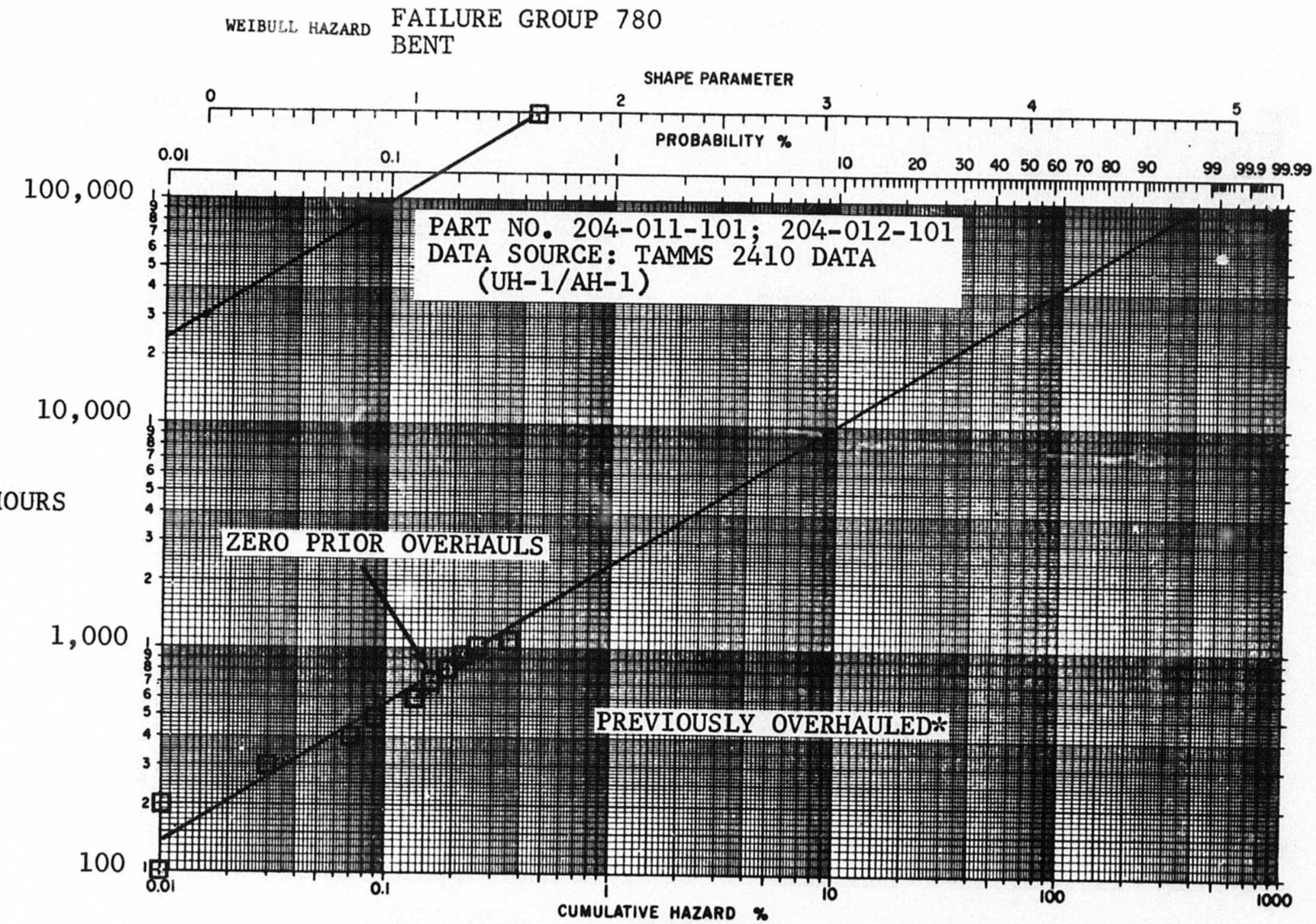


* Data were inadequate to analyze (ten assemblies)

Figure A-4. Concluded.

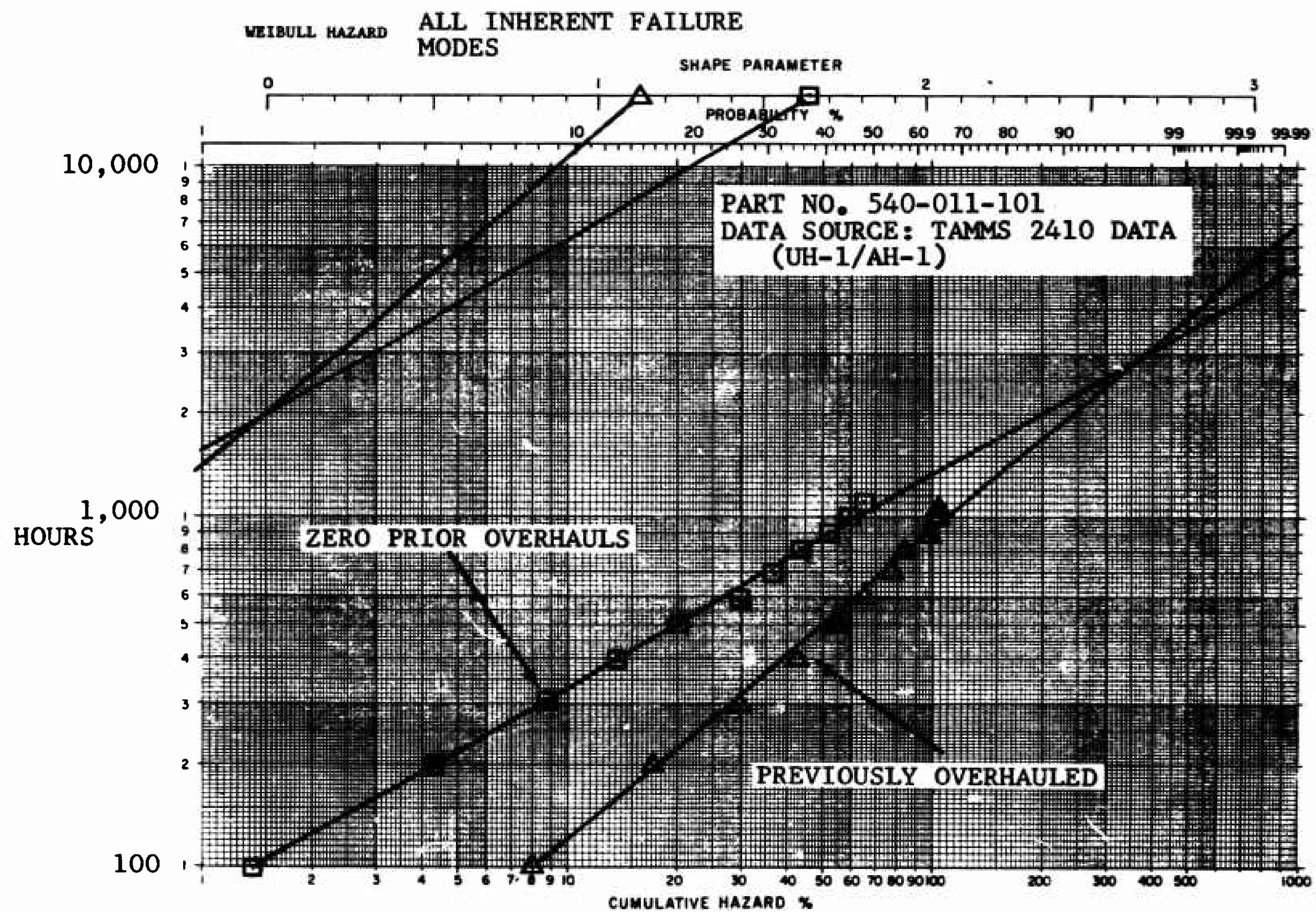


Figure A-5. Weibull hazard rate plots of UH-1C/AH-1G type main rotor hub.

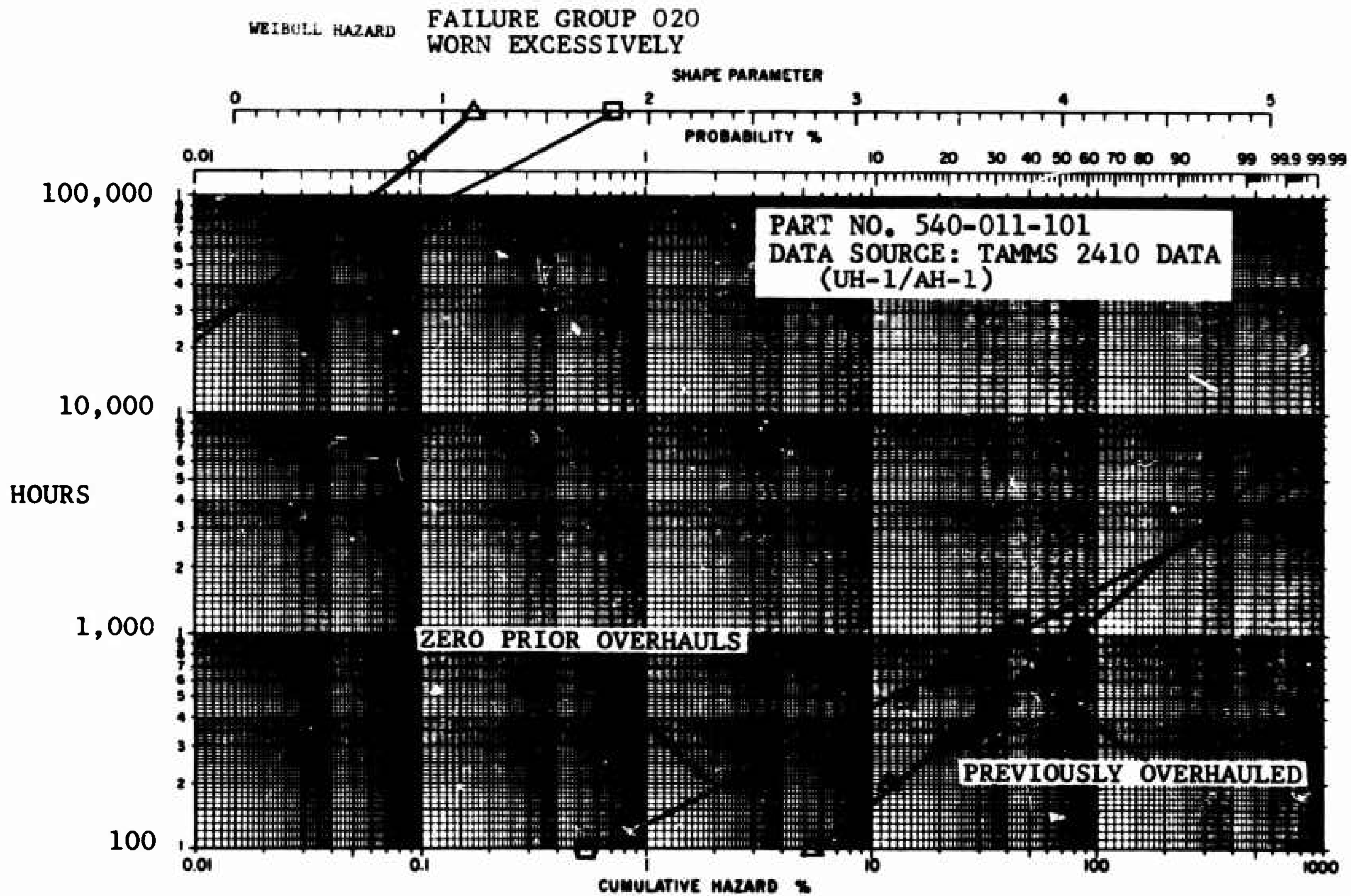


Figure A-5. Continued.

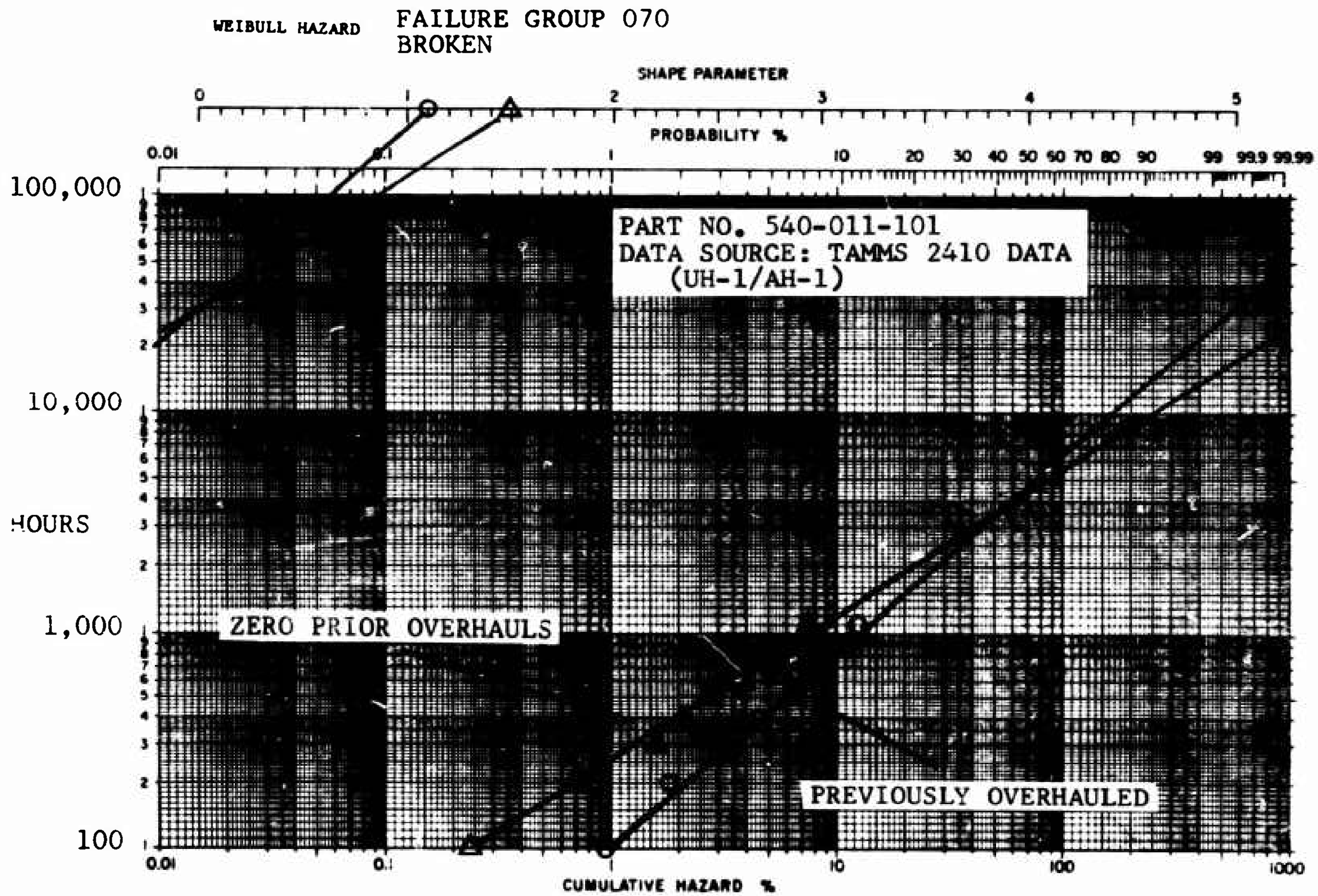


Figure A-5. Continued.

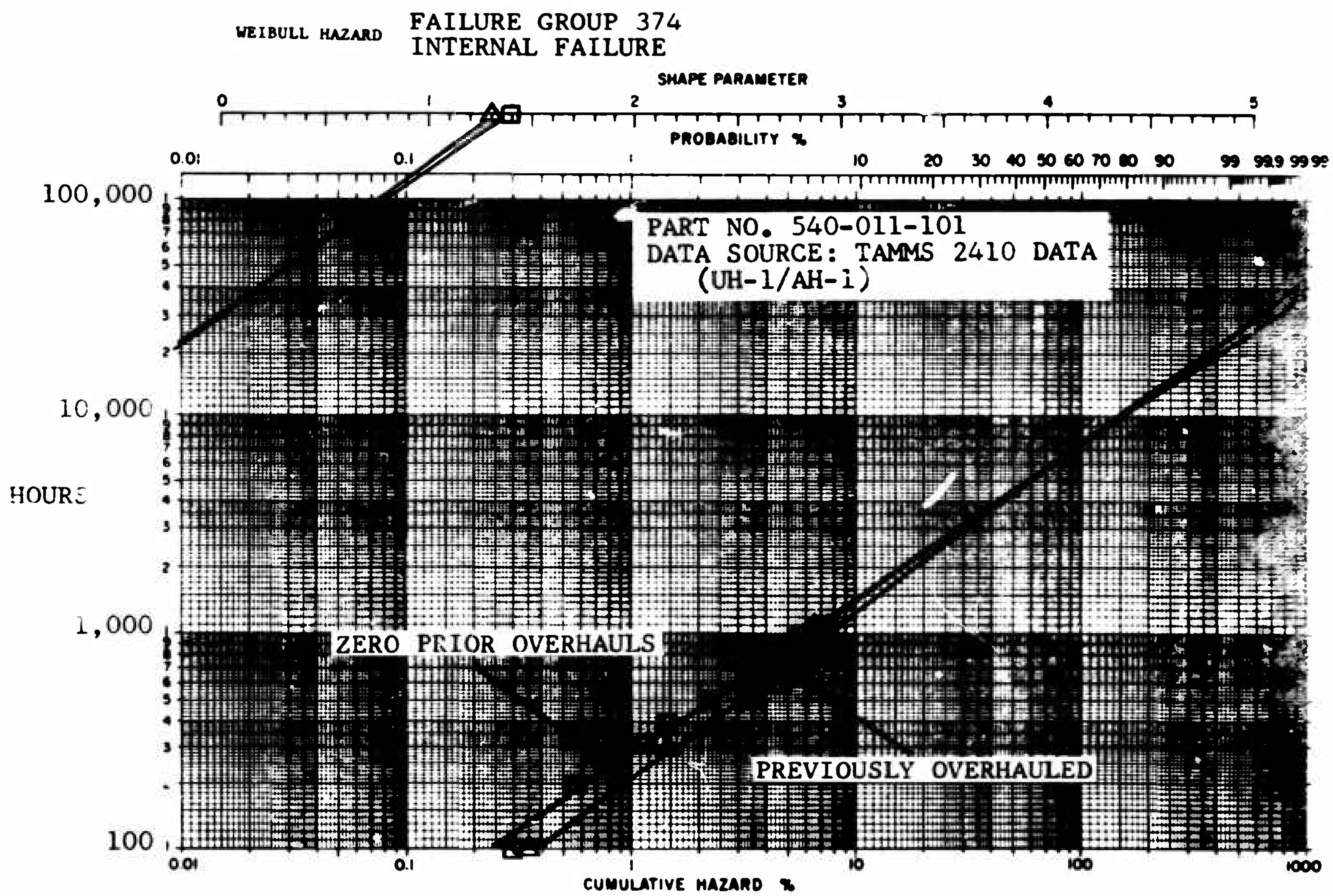
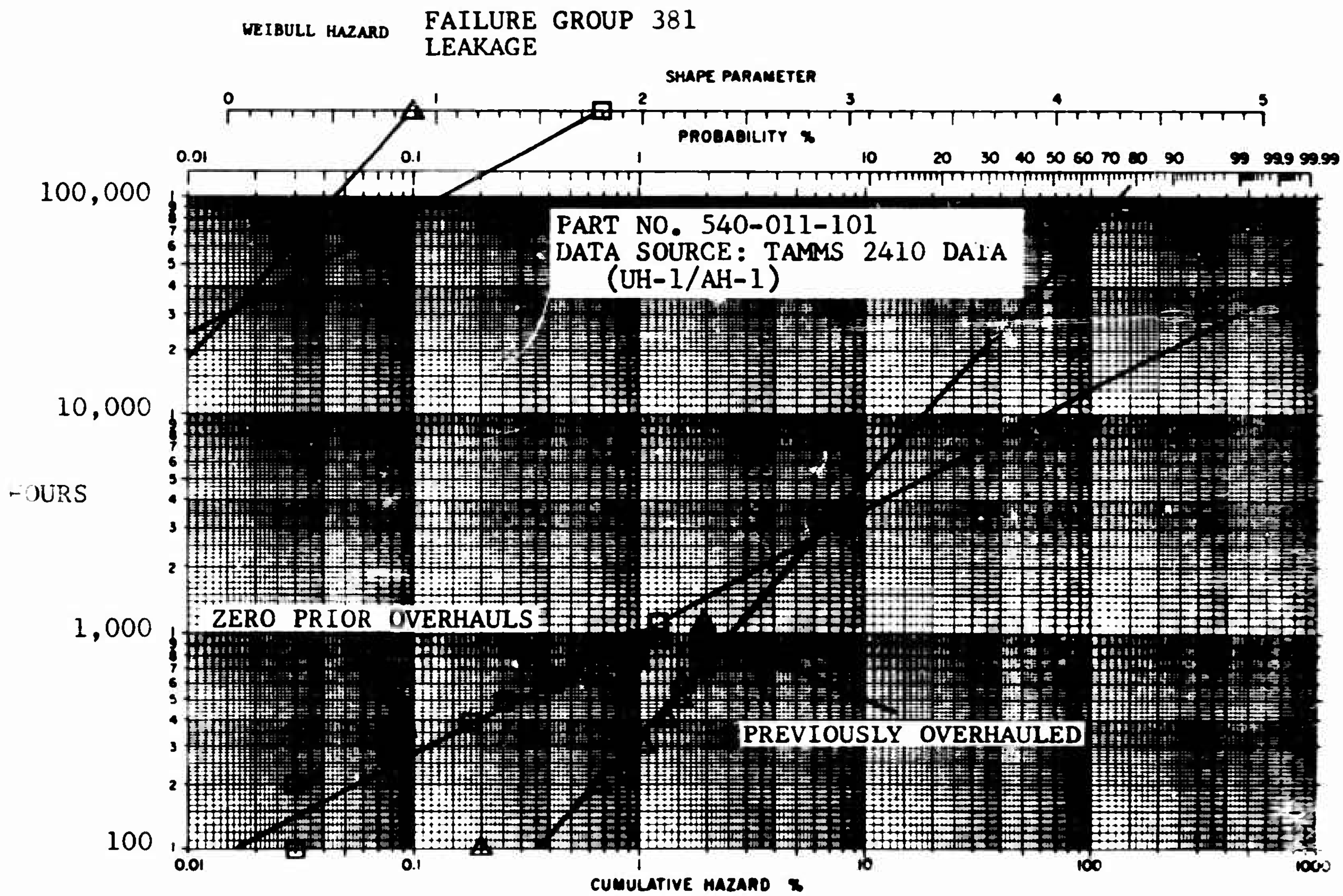


Figure A-5. Continued.



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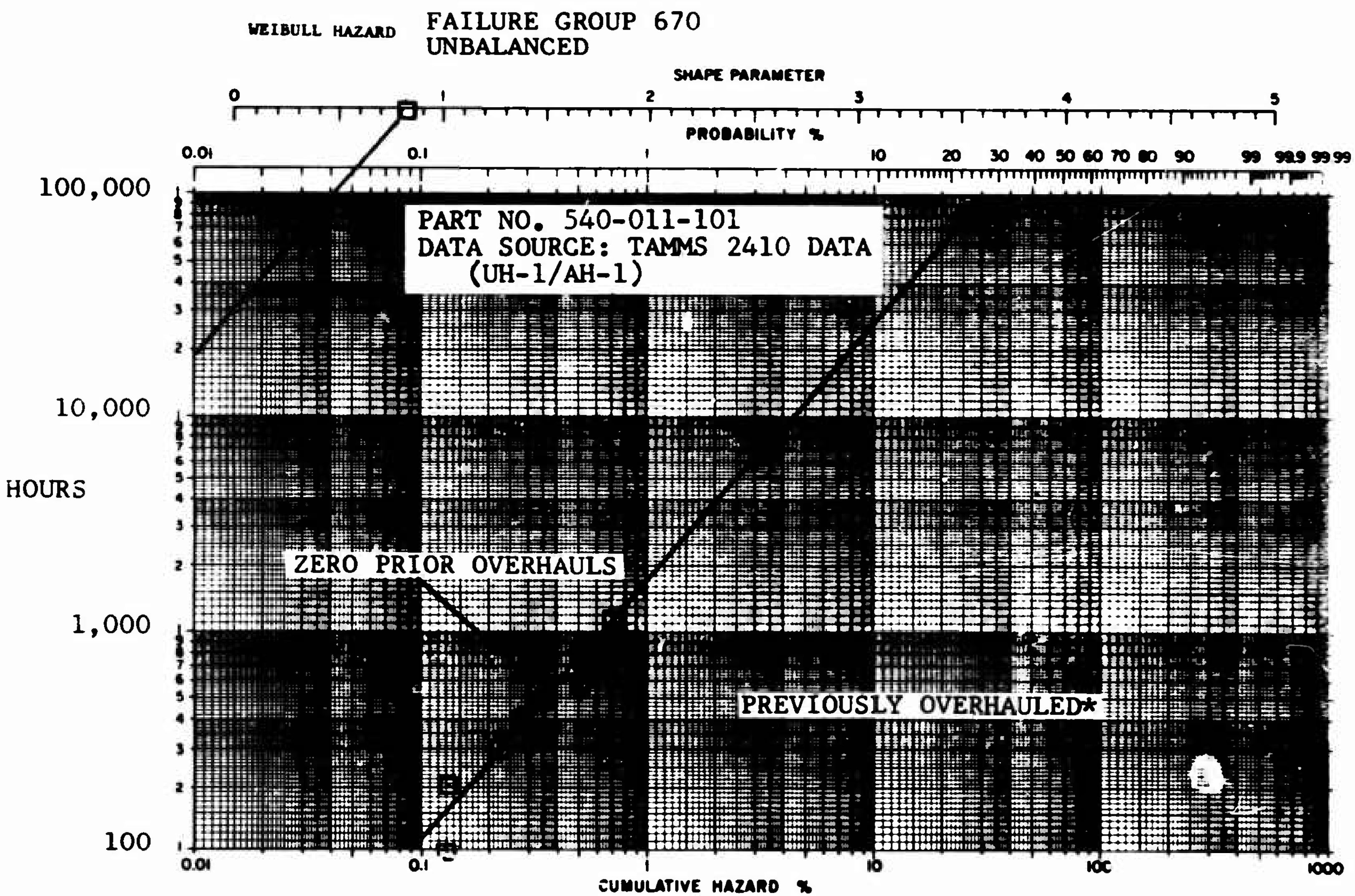
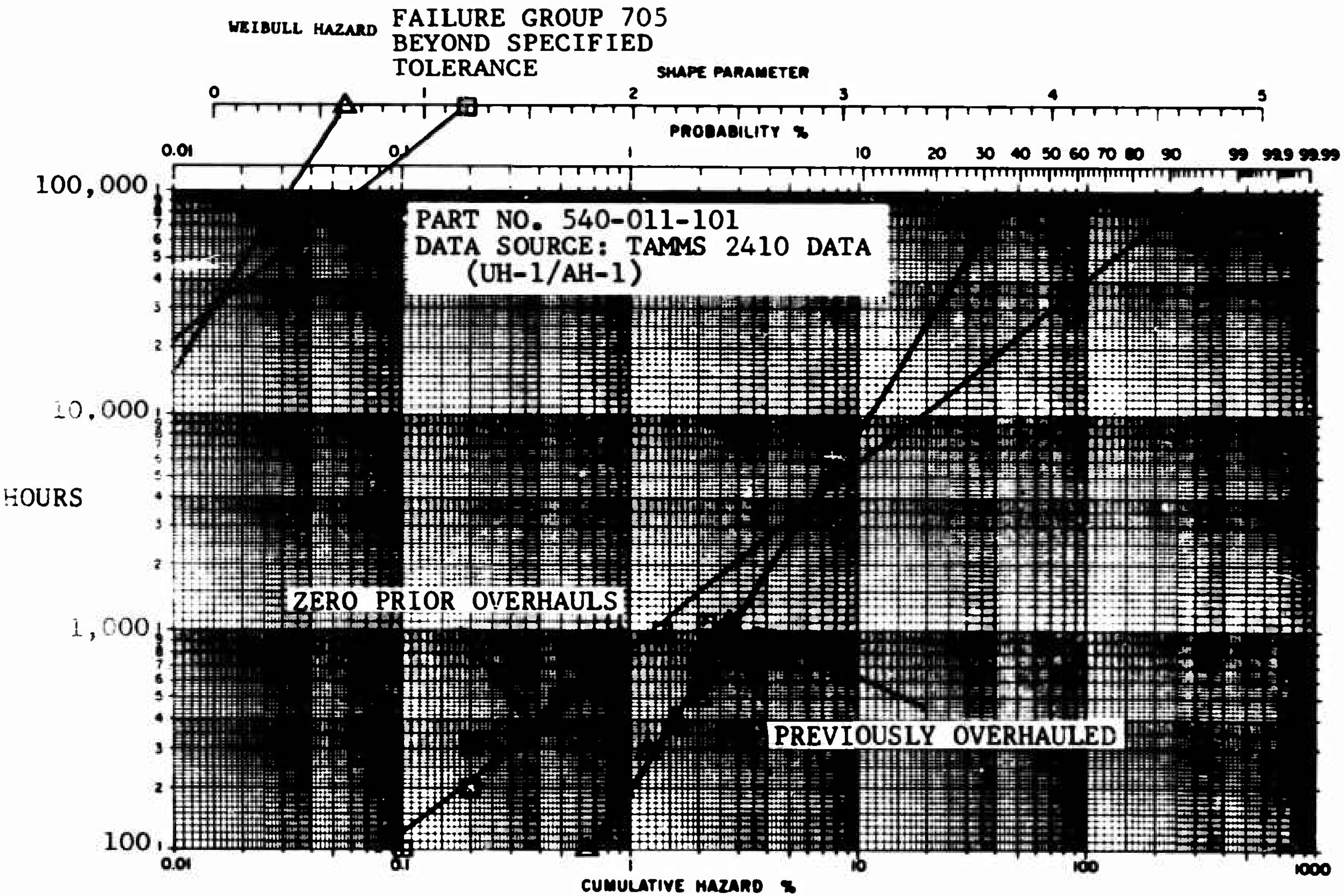


* Data were inadequate to analyze (one assembly)

Figure A-5. Continued.



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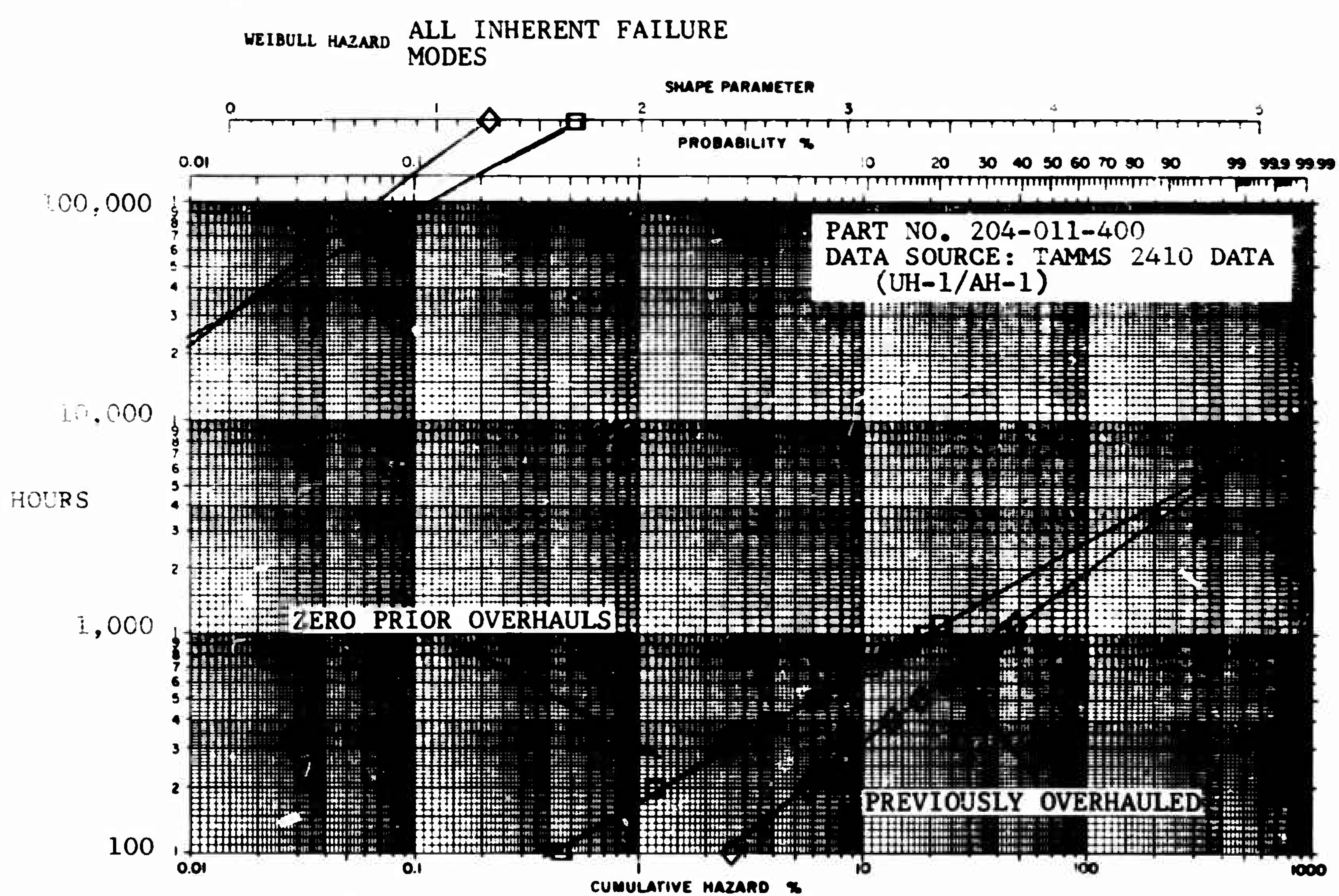


Figure A-6. Weibull hazard rate plots of UH-1B/D/H type swashplate.

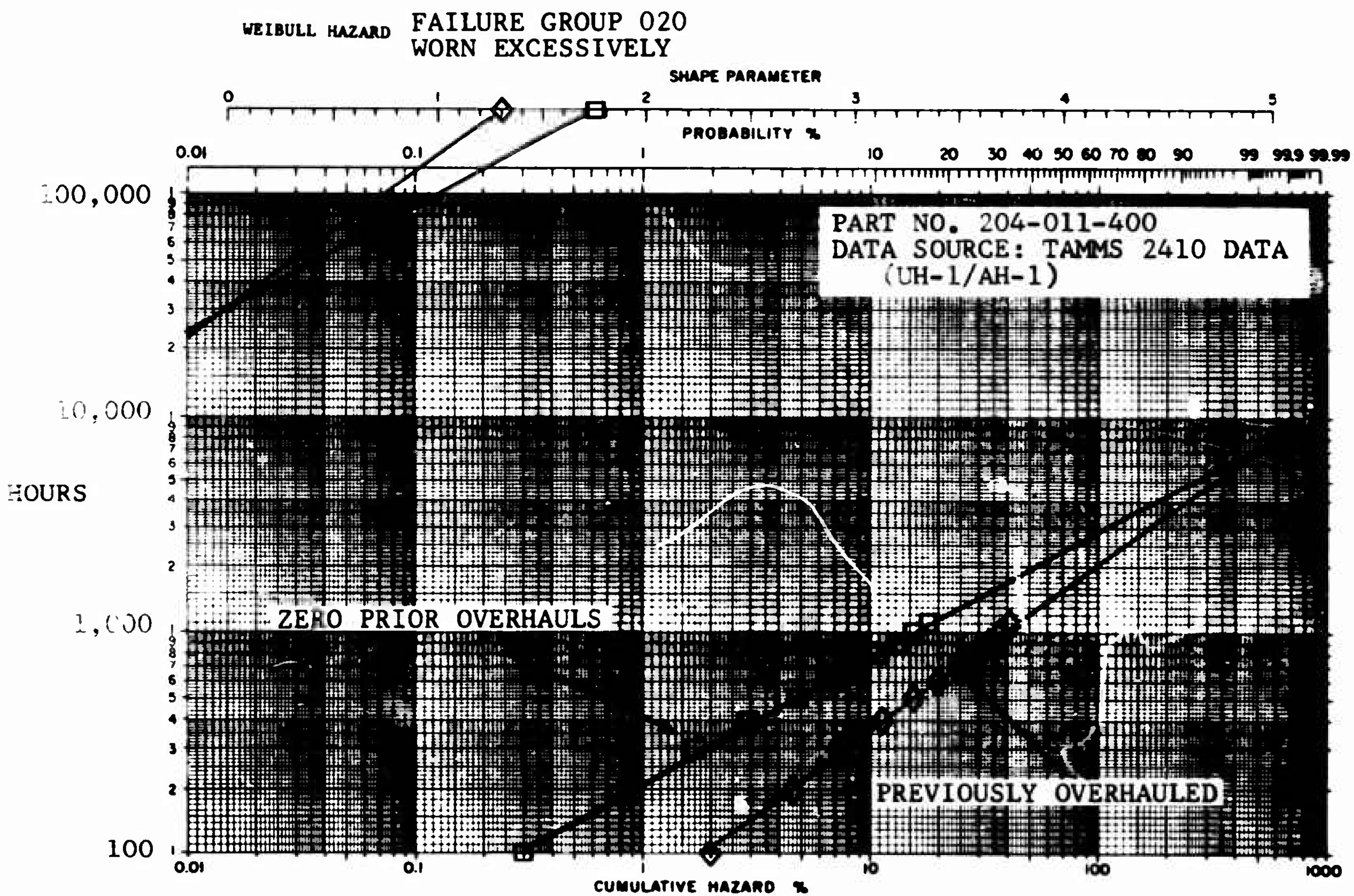
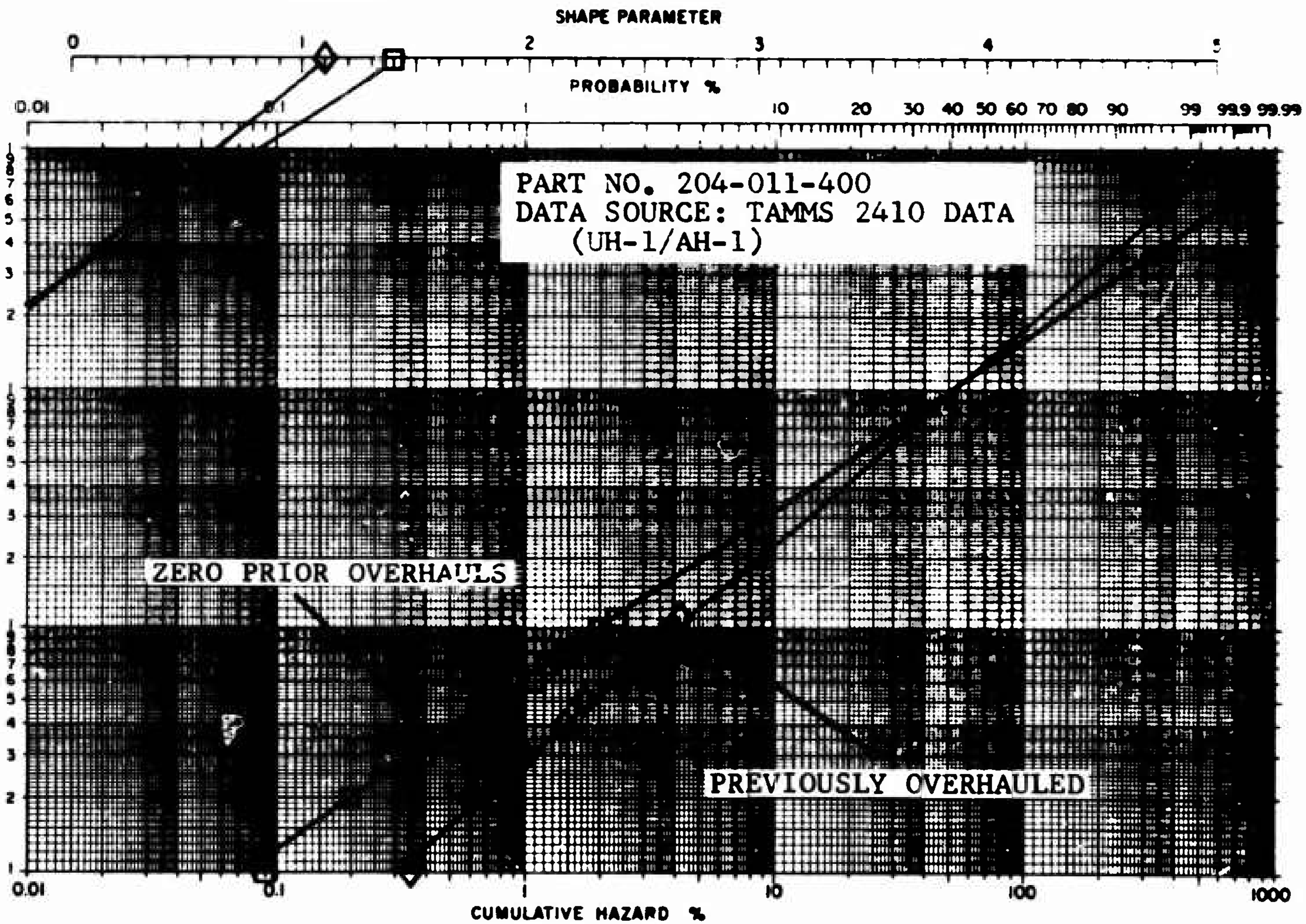


Figure A-6. Continued.

WEIBULL HAZARD FAILURE GROUP 070
BROKEN



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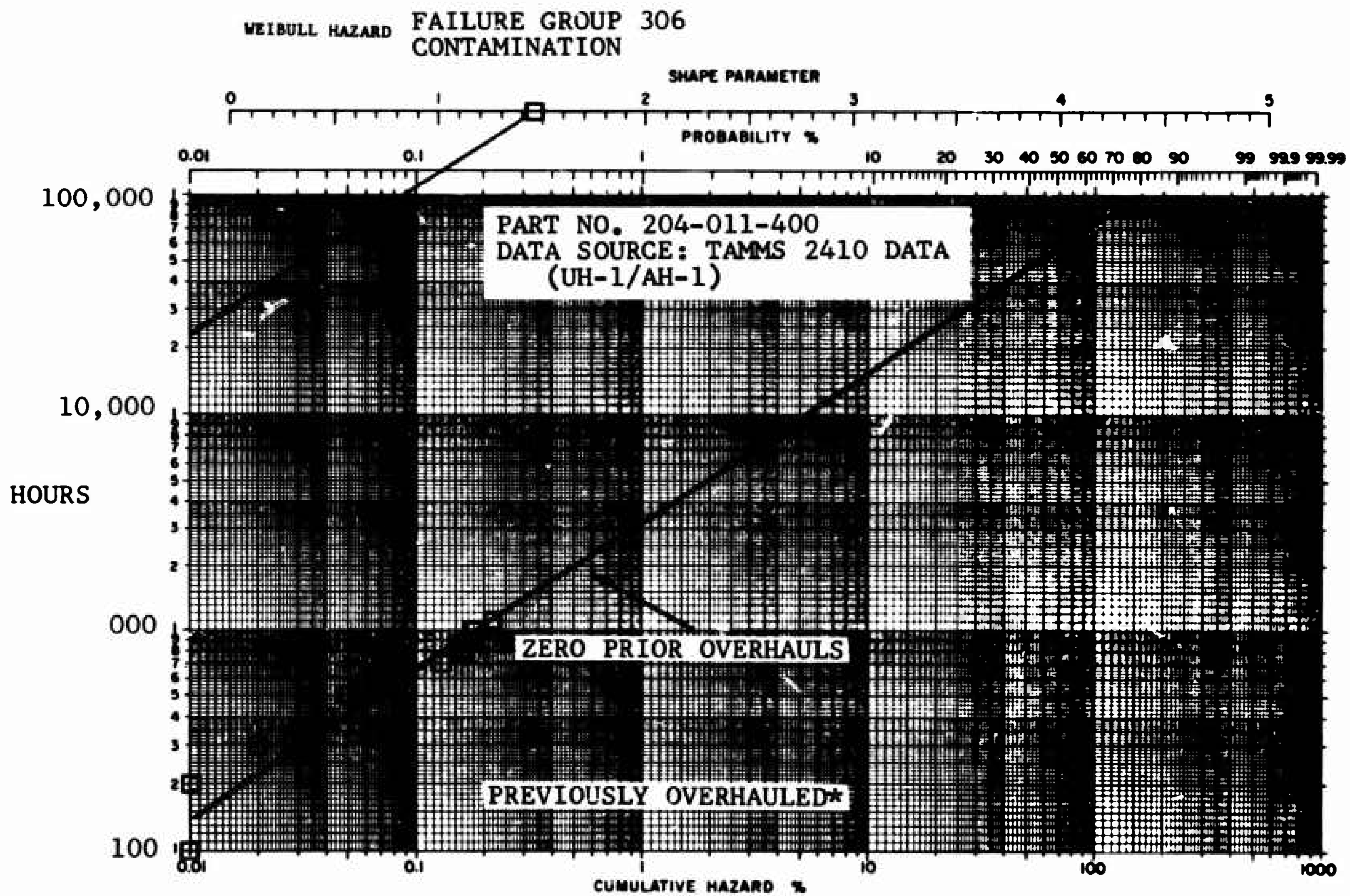
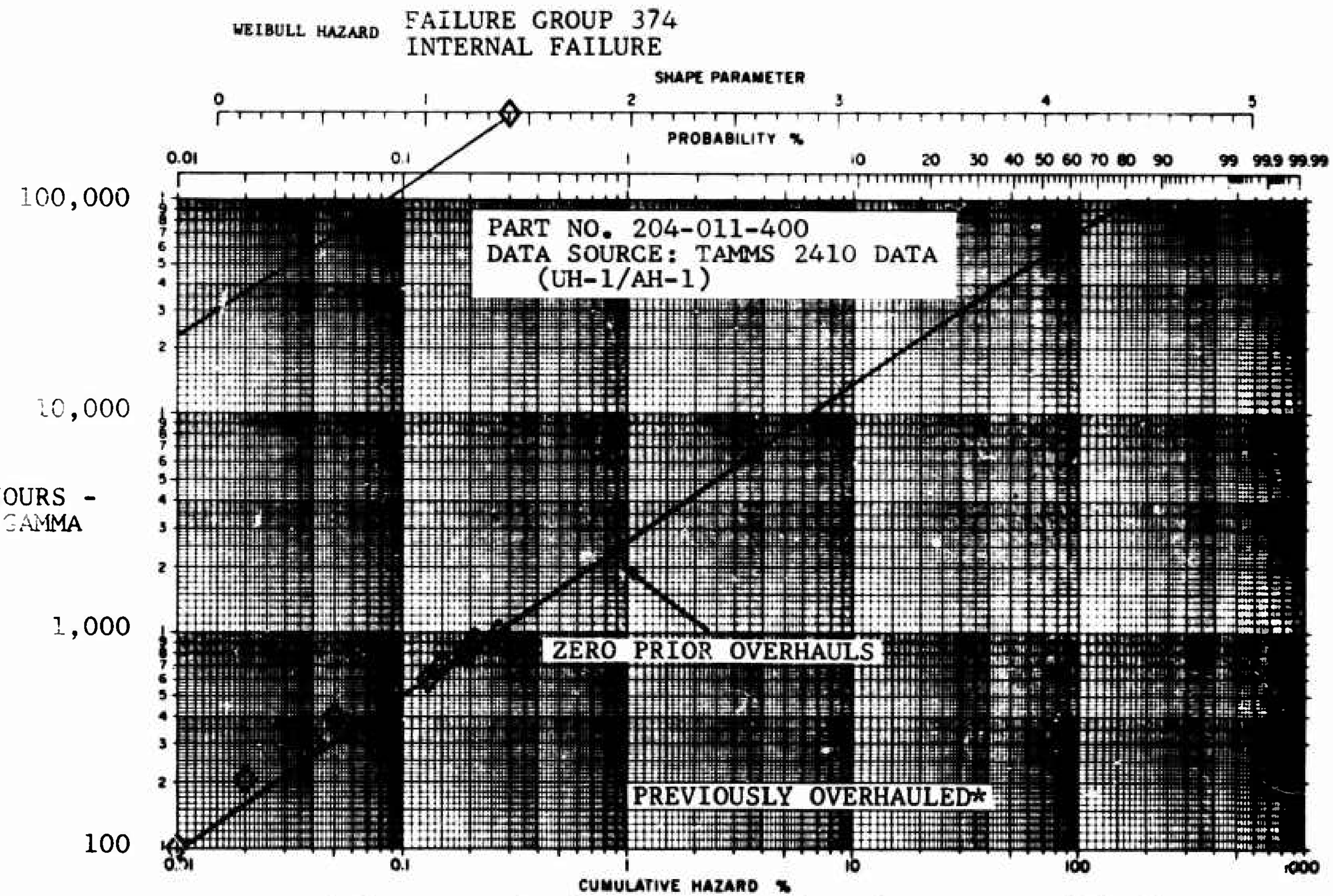


* Data were inadequate to analyze (one assembly)

Figure A-6. Continued.



* Data were inadequate to analyze (seven assemblies)

Figure A-6. Continued.

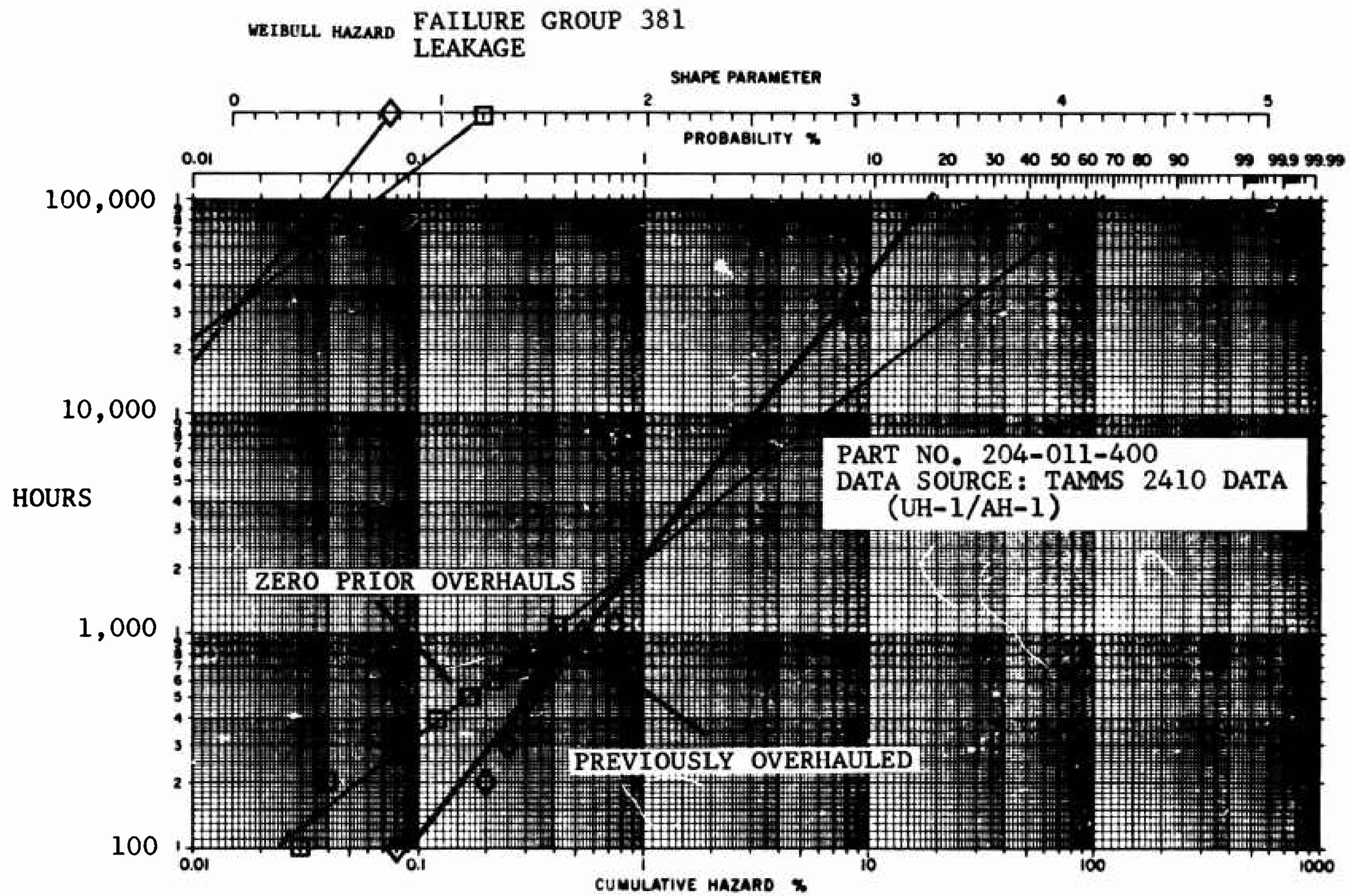


Figure A-6. Continued

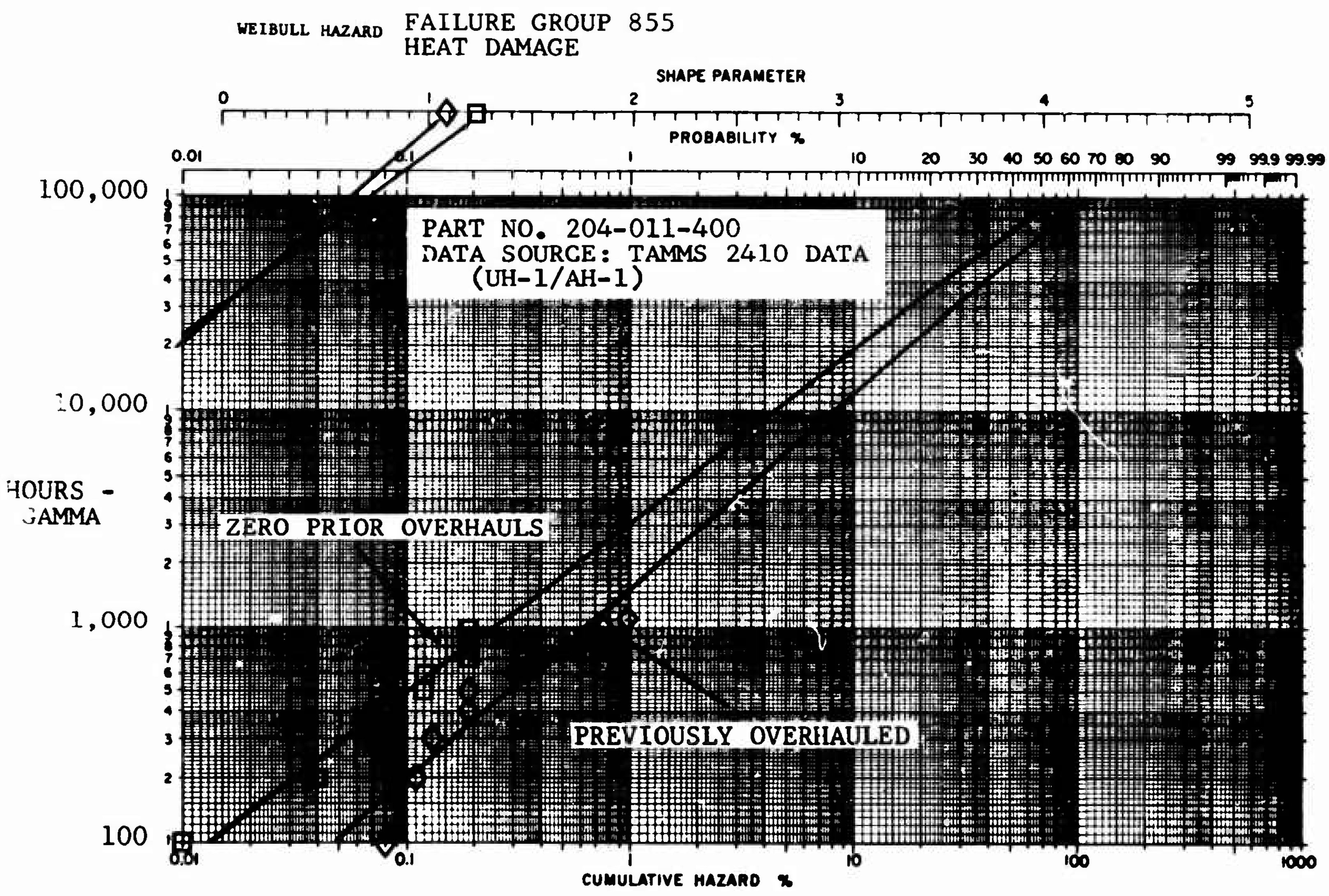


Figure A-6. Concluded.

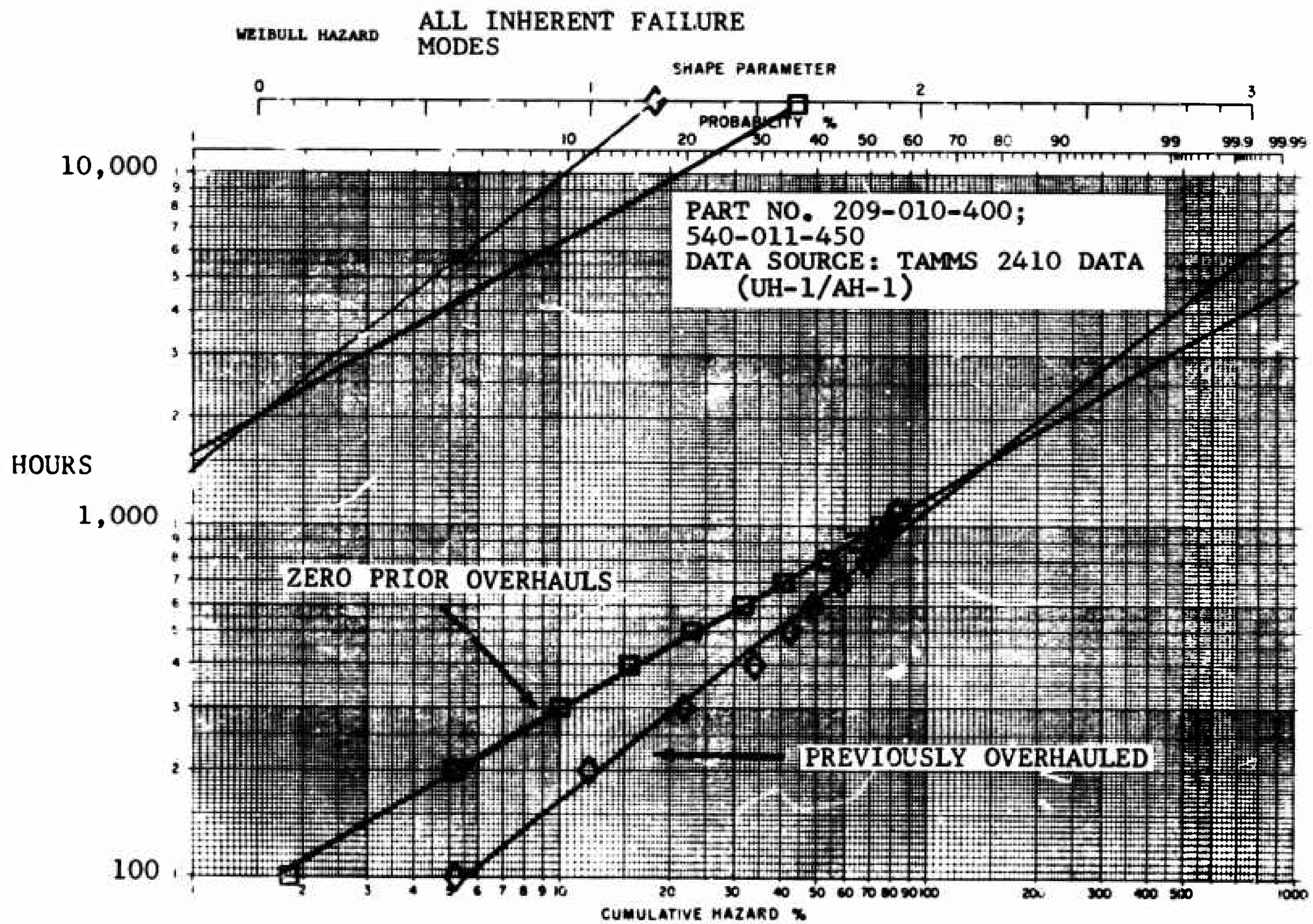


Figure A-. Weibull hazard rate plots of UH-1C/AH-1G type swashplate.

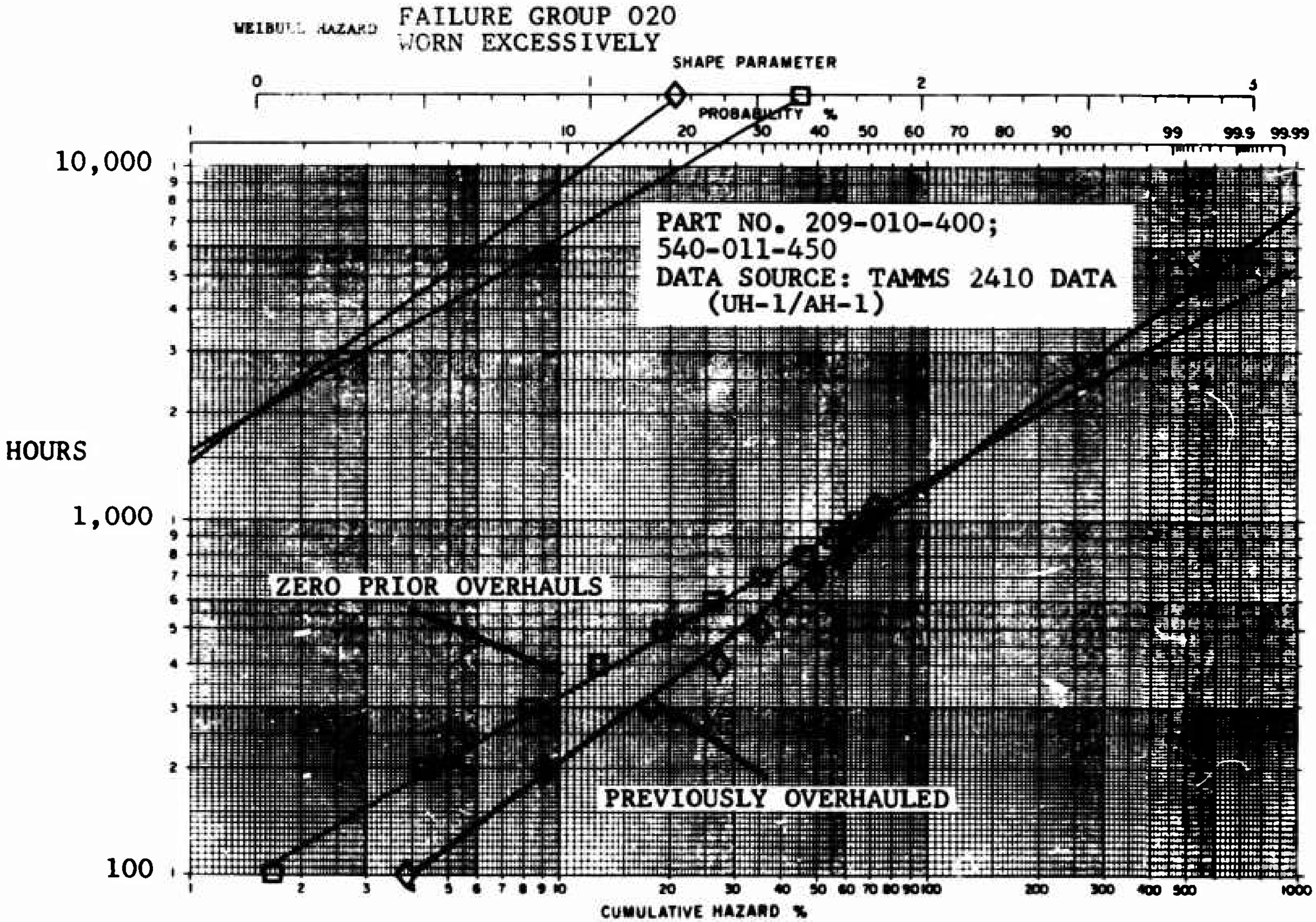


Figure A-7. Continued.

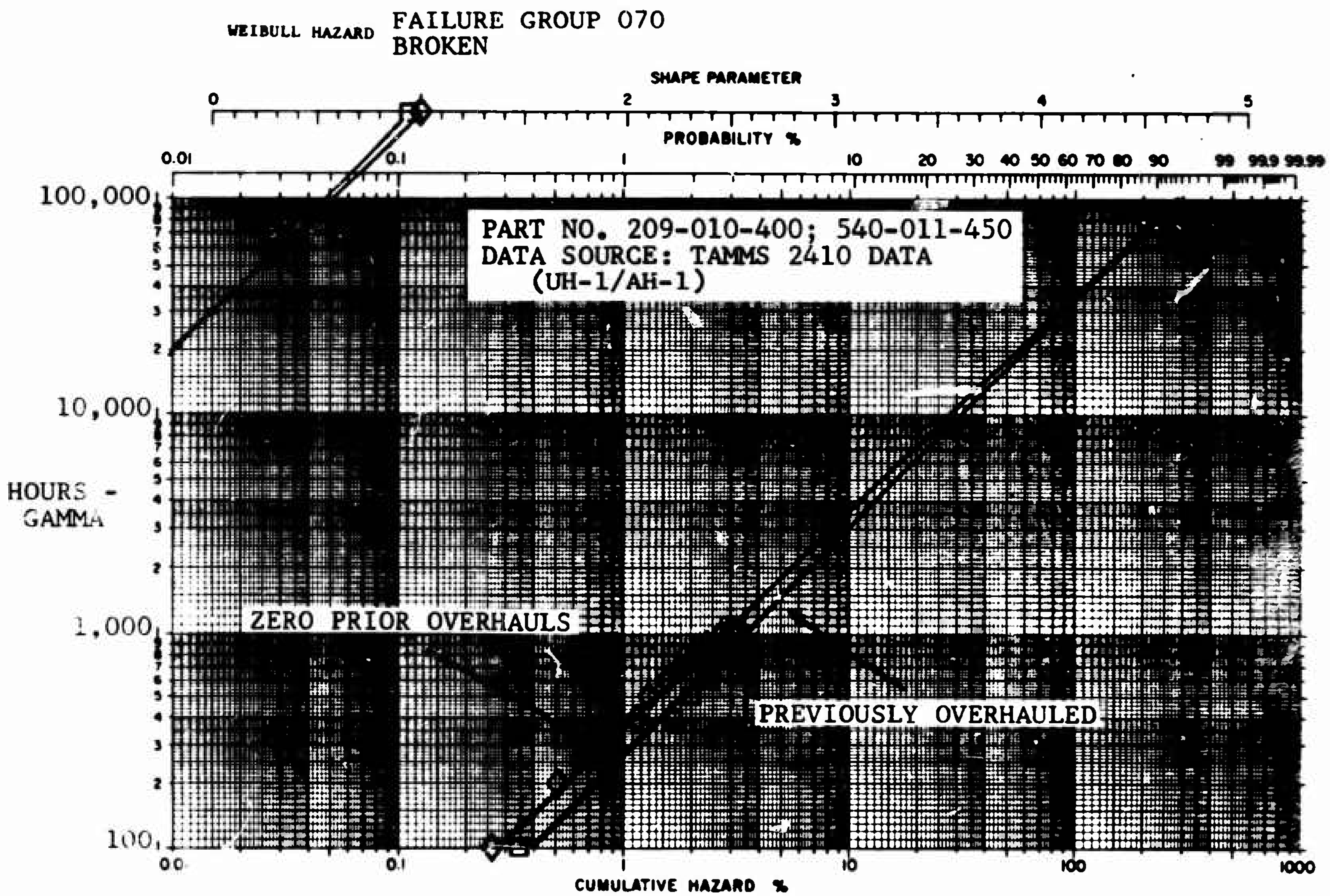
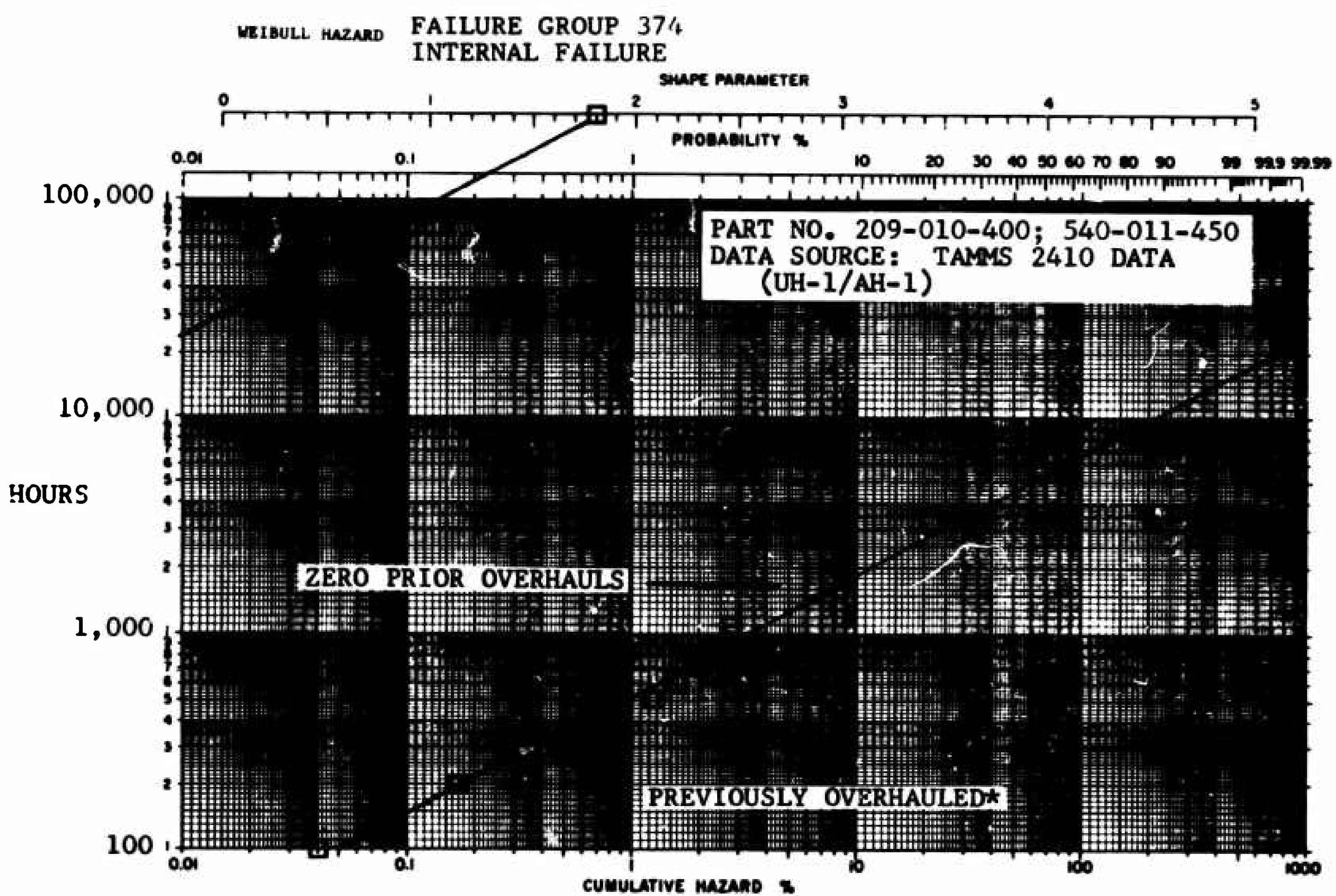
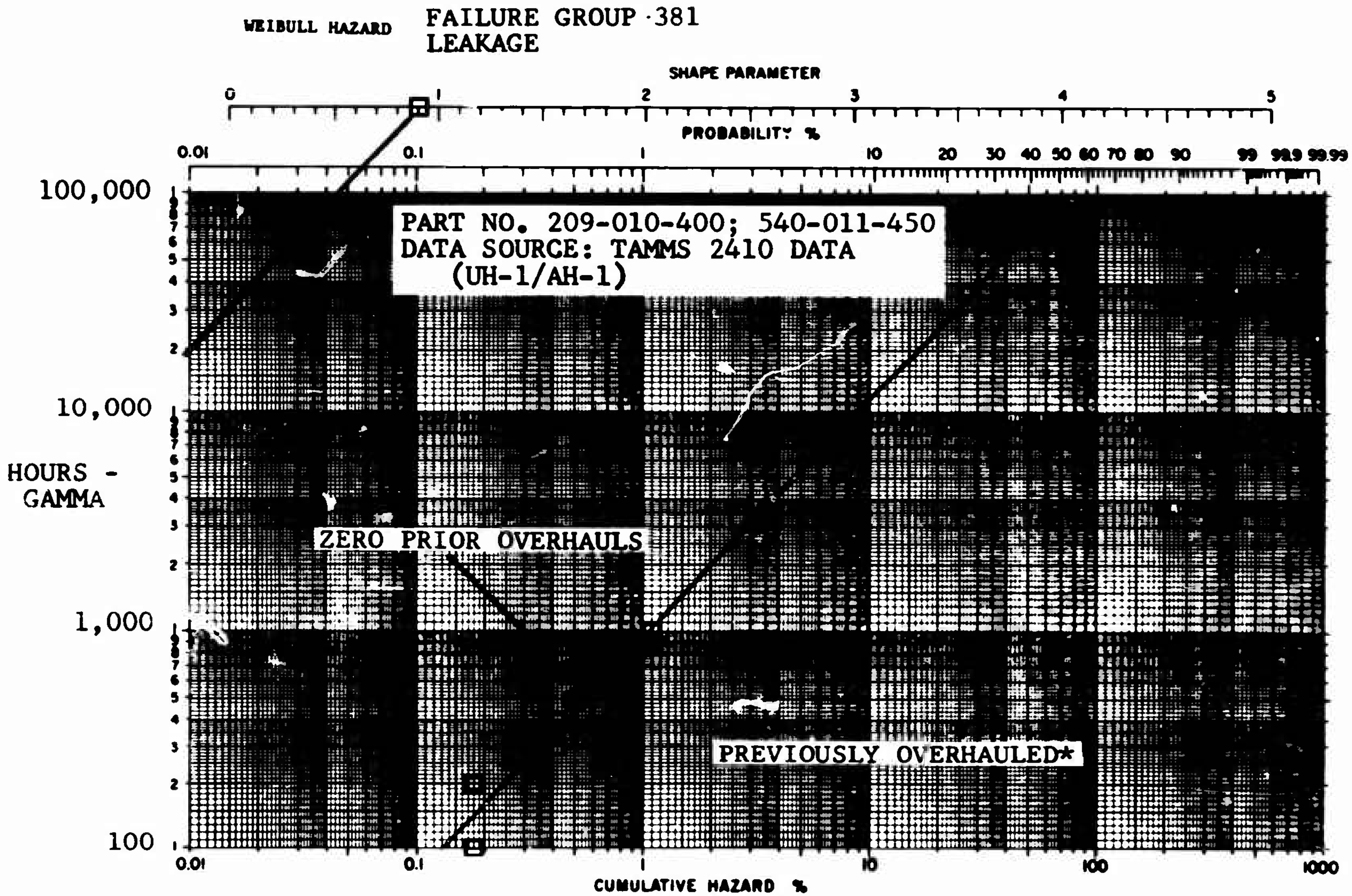


Figure A-7. Continued.



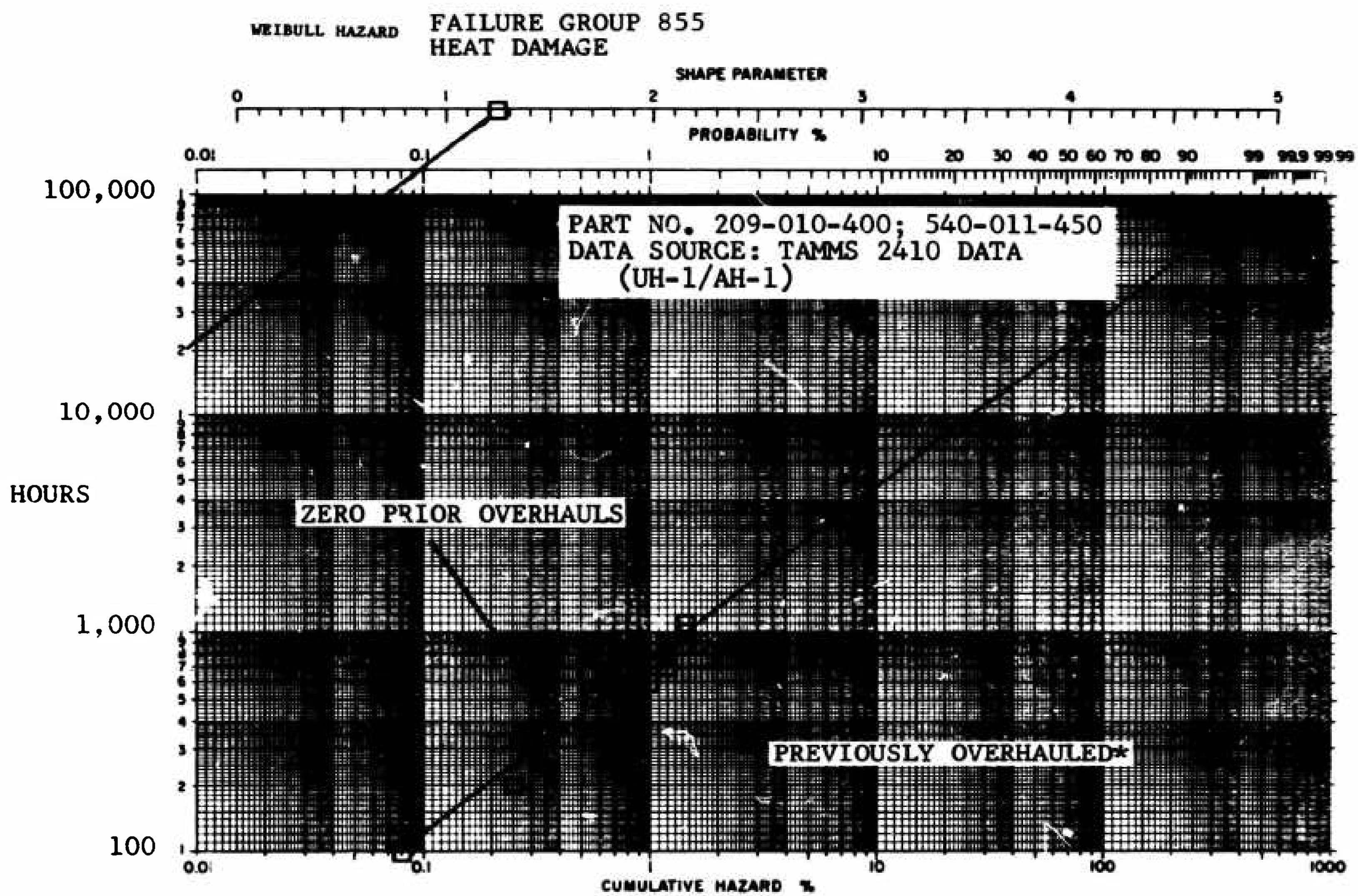
* Data were inadequate to analyze (seven assemblies)

Figure A-7. Continued.



* Data were inadequate to analyze (eleven assemblies)

Figure A-7. Continued.



* Data were inadequate to analyze (eleven assemblies)

Figure A-7. Concluded.

TABLE B-1. MAIN TRANSMISSION FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 204-040-0[illegible]-1/5

Component	Failure Mode	Cause	Effect*	Warning
SPUR GEAR 204-040-108-7	Bending Fatigue Failure - (Gear Tooth Break)	Unclean material	This failure can result in the loss of gear function. Secondary damage is caused by particle ingestion. Currently, a maintenance procedure exists for hand-stoning the flaked area. This mode of failure has been virtually eliminated, today, by use of "clean steel" produced through vacuum arc remelting processes, excellent heat treating controls, accurate tooth spacing, and the use of root fillet forms with a minimum notch concentration factor.	Transmission chip detector.
	Surface Compressive Failure - (Pitting and Spalling) - These modes are caused by tensile cracking of high asperity contacts through the thin oil film followed by rapid hydraulic propagation.	Breakdown of lubrication, contamination, unclean material	Direct effect on the gear is minimal. The following items on pitted/spalled sun gears have been checked and found to be within specified or tolerable limits: 1. Gear tooth geometry 2. Tooth spacing 3. Surface finish 4. Material hardness Further, no discrepancies have been found in the microstructure or retained austenite. Secondary damage is caused by the ingestion of particles.	Transmission chip detector.
	Gear Scuffing Failure - There exists a critical temperature at which the oil in the conjunction between two loaded-moving gear teeth will cease to lubricate and severe metal contact will follow and result in scuffing--the melting of a thin layer of tooth surface material.	Inadequate lubrication, excessive heat, overstress	Reduction in gear life will occur due to the melting of the surface. Secondary damage should be minimal.	Transmission chip detector.
UPPER SUN GEAR 204-040-330-3	Bending Fatigue Failure - (Gear Tooth Edge Break)	Unclean material	This failure can result in the loss of gear function. Secondary damage is caused by particle ingestion. The particles (broken tooth edges) can cause premature replacement of other	Transmission chip detector.

TABLE B-1. - Continued

Component	Failure Mode	Cause	Effect*	Warning
			components. Currently, a maintenance procedure exists for hand-stoning the flaked area. This mode of failure has been virtually eliminated today, by use of vacuum arc remelting processes, excellent heat treating controls, accurate tooth spacing, and the use of root fillet forms with a minimum notch concentration factor.	
	Surface Compressive Failure - (Pitting and Spalling) - These modes are caused by tensile cracking of high asperity contacts through the thin oil film followed by rapid hydraulic propagation.	Breakdown of lubrication, contamination, unclean material	Direct effect on the gear is minimal. The following items on pitted/spalled sun gears have been checked and found to be within specified or tolerable limits: 1. Gear tooth geometry 2. Tooth spacing 3. Surface finish 4. Material hardness Further, no discrepancies have been found in the microstructure or retained austenite. Secondary damage is caused by the ingestion of particles.	Transmission chip detector.
	Gear Scuffing Failure - There exists a critical temperature at which the oil in the conjunction between two loaded-moving gear teeth will cease to lubricate and severe metal contact will follow and result in scuffing--the melting of a thin layer of tooth surface material.	Inadequate lubrication, excessive heat, overstress	Reduction in gear life will occur due to the melting of the surface. Secondary damage should be minimal.	Transmission chip detector.
RING GEAR ASSEMBLY 204-040-331-5	Bending Fatigue Failure - (Gear Tooth Edge Break) - Inadequate gear tooth edge has a sharp corner that becomes brittle after nitriding. The gear teeth are highly loaded at the tooth edge.	Unclean material	This failure can result in the loss of gear function. Secondary damage is caused by particle ingestion. The particles (broken tooth edges) can cause premature replacement of other components. Currently, a maintenance procedure exists for hand-stoning the flaked area. This mode of failure has been virtually eliminated today by use of "clean steel" produced through vacuum arc remelting processes, excellent heat	Transmission chip detector.

TABLE B-1. - Continued

Component	Failure Mode	Cause	Effect*	Warning
			treating control , accurate tooth spacing, and the use of root fillet forms with a minimum notch concentration factor.	
	Surface Compressive Failure - (Pitting and Spalling) - These modes are caused by tensile cracking of high asperity contacts through the thin oil film followed by rapid hydraulic propagation.	Breakdown of lubrication, contamination, unclean material	Direct effect on the gear is minimal. The following items on pitted/spalled sun gears have been checked and found to be within specified or tolerable limits: 1. Gear tooth geometry 2. Tooth spacing 3. Surface finish 4. Material hardness Further, no discrepancies have been found in the microstructure or retained austenite. Secondary damage is caused by the ingestion of particles.	Transmission chip detector.
	Gear Scuffing Failure - There exists a critical temperature at which the oil in the conjunction between two loaded-moving gear teeth will cease to lubricate and severe metal contact will follow and result in scuffing--the melting of a thin layer of tooth surface material.	Inadequate lubrication/excessive heat	Reduction in gear life will occur due to the melting of the surface. Secondary damage should be minimal.	Transmission chip detector.
FREEWHEELING CLUTCH ASSEMBLY** *** X-131720	Wear - Occurs in the freewheeling position. It is the result of the inner ring rotating faster than the outer ring causing the tips of the sprags to rub on moving metal.	Excessive wear, overheat	Wear is a normal process in the freewheeling clutch. Excessive wear can reduce the fatigue life. Slight degradation in clutch performance can be noticed.	None - Wear would be found only on disassembly. ARADMAC study indicates that (many) items removed for wear were still serviceable.
	Broken - Brittle surface areas of coarse martensite have been found to cause broken sprags.	Unclean material, overstress	Broken sprags will cause little (if any) degradation in aircraft performance. Broken cages could cause at worst an autorotation (forced landing). Remove broken cages and sprags from the aircraft.	None - No secondary damage since centrifugal force will prevent chips from damaging bearings.

TABLE B-1. - Continued

Component	Failure Mode	Cause	Effect*	Warning
	Missing - Missing sprags could possibly occur during input quill assembly.	Maintenance error	Missing sprags will cause little degradation in aircraft performance. It is possible to roll the sprags over in an extreme overtorque producing a forced landing autorotation. However, in testing, this failed to occur with one-third of sprags missing at 180 percent of maximum horsepower.	None - However, if found, remove assembly from service.
TRIPLEX BEARING*** 204-040-246-3	Fatigue	Unclean material, overstress	The rate of progression of the failure is slow allowing the production of debris to give sufficient warning through the chip detector.	Transmission chip detector.
PINION*** 204-040-700-1	Fatigue	Unclean material, overstress	The rate of progression of the failure is slow allowing the production of debris to give sufficient warning through the chip detector.	Transmission chip detector.
BEARINGS**** 204-040-143-1 204-040-144-1	Fatigue	Unclean material, overstress	The rate of progression of the failure is slow allowing the production of debris to give sufficient warning through the chip detector.	Transmission chip detector.
PINION*** 204-040-104-3	Bending Fatigue Failure - Tooth bending fatigues through the root progressing under the rim of the gear.	Unclean material	Full progression of the bending fatigue failure will result in the loss of gear teeth and the subsequent loss of tail rotor. Pilot manuals outline procedures for reacting to the loss of tail rotor. If the loss is in flight, the situation is critical but not extremely critical. However, the loss of tail rotor in a hover is an extremely critical situation. The ultimate danger in landing the aircraft with this malfunction is the tendency of the aircraft to turn over.	The transmission chip detector could be of some assistance. However, the rate of progression of this failure is suspected to be quite rapid. The first indication to the pilot is the loss of his anti-torque controls.
LOWER PLANETARY BEARING RETAINER 204-040-133-1	Debris Damage - The ingestion of foreign particles, primarily, from a fatiguing roller set.	Fatiguing of the roller set	The debris can cause the retainer to be torn up. This would cause the loss of proper function of one of the gears. A precautionary situation would not arise unless multiple coincidental failures of the retainers occurred.	Transmission chip detector.

TABLE B-1. - Continued

Component	Failure Mode	Cause	Effect*	Warning
.OWER PLANETARY EARING ROLLER SET .)4-040-`25-1	Fatigue	Unclean material, overstress	The rate of progression is slow allowing the production of debris. The uebris in part may be trapped by the retainer.	Transmission chip detector.
.WER SUN GEAR .5-040-229-1	Bending Fatigue Failure - (Gear Tooth Break)	Unclean material.	This failure can result in the loss of gear function. Secondary damage is caused by particle ingestion. The particles (broken tooth edges) can cause premature replacement of other components. Currently, a maintenance procedure exists for hand-stoning the flaked area. This mode of failure has been virtually eliminated today by use of "clean steel" produced through vacuum arc remelting processes, excellent heat treating controls, accurate tooth spacing, and the use of root fillet forms with a minimum notch concentration factor.	Transmission chip detector.
	.urface Compressive Failure - (Pitting and Spalling) - These modes are caused by tensile cracking of high asperity contacts through the thin oil film followed by rapid hydraulic propagation.	Breakdown of lubrication, contamination, unclean material	Direct effect on the gear is minimal. The following items on pitted/spalled sun gears have been checked and found to be within specified or tolerable limits: 1. Gear tooth geometry 2. Tooth spacing 3. Surface finish 4. Material hardness Further, no discrepancies have been found in the microstructure of retained austenite. Secondary damage is caused by the ingestion of particles.	Transmission chip detector.
	Gear Scuffing Failure - There exists a critical temperature at which the oil in the conjunction between two loaded-moving gear teeth will cease to lubricate and severe metal contact will follow and result in scuffing--the melting of a thin layer of tooth surface material.	Inadequate lubrication, excessive heat, overstress	Reduction in gear life will occur due to the melting of the surface. Secondary damage should be minimal.	Transmission chip detector.

TABLE B-1. - Concluded

* In addition to describing the potential effect on the part, subsystem or aircraft, this column includes a discussion of conditions which could limit or prevent the failure mode from occurring.

** In order for the occurrence of a failure of the freewheeling clutch to result in a catastrophe to the aircraft, the following two events must occur:

CASE I

(1) The engine power turbine rpm must be decreased sufficiently in order that the freewheeling clutch should become disengaged (i.e., a situation of a real or practice autorotation).

(2) The freewheeling clutch fails to become disengaged, then the rotor rpm (needed for autorotation) could be bled off too rapidly for a safe autorotation since the rotors are attempting to drive the engine.

CASE II

(1) In a practice autorotation, due to circumstances unknown, the rotor rpm is being bled off too rapidly for a safe autorotation. The attempt is made to re-engage the clutch.

(2) The clutch fails to re-engage.

In TAMMS 2407 data, ARADMAC overhaul data, and BHC DMR's, there is no confirmed record of a clutch which failed to disengage or engage.

*** Main Input Quill 205-040-263-3.

**** Tail Rotor Output Quill 204-040-207-13.

TABLE B-2. 42-DEGREE GEARBOX FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 204-040-003-37

Component	Failure Mode	Cause	Effect	Warning
DUPLEX BEARING 204-040-143-1	Excessive Wear	Worn excessively - Wear is a normal mode of deterioration for the duplex bearing. The wear can be accelerated by excessive temperature, lack of lubrication, and excessive power.	Wear generally produces vibration as its by-product. Severe wear can also result in low hardness values of the bearing races.	Vibration in region of 42-degree gearbox.
	Maintenance Error	Corrosion - Duplex bearing is improperly prepared for shipment and storage.	Bearing must be replaced.	Spares inspection.
	Contamination	Debris damage - Ingestion of foreign particles through the gearbox oil system.	Races and balls can be severely scored.	42-degree gearbox chip detector.
CASE ASSEMBLY 204-040-513-1	Fatigue	Cracked - Fatigue failure in aluminum/magnesium case.	Lubrication can be lost, causing bearing and coupling wear.	Daily inspection procedures.
	Maintenance Error	Corrosion - Case was improperly prepared for shipment or storage.	Case assembly must be replaced and reworked.	Spares inspection.
COUPLING 204-040-603-7	Surface Compressive Failure - (Pitting) is caused by tensile cracking of high asperity contacts through the thin oil film followed by rapid hydraulic propagation.	Breakdown of lubrication, contamination, unclean material	Direct effect is minimal. Secondary damage can be produced through the ingestion of these particles.	42-degree gearbox chip detector.
	Excessive Wear	Worn excessively - Wear is produced (accelerated) by a loss of lubrication. Grease leaks past boot.	Wear produces a shortened fatigue life. Premature removal can be caused by wear.	Excessive vibration in the region of the 42-degree gearbox.
	Overheat	Overheat - is caused by a lack of lubrication. Grease leaks past boot.	Excessive heat can produce wear or distortion of the gearbox components.	Excessive vibration in the region of the 42-degree gearbox.

TABLE B-2. - Concluded

Component	Failure Mode	Cause	Effect	Warning
	Maintenance Error	Corrosion - Coupling was improperly prepared for shipment or storage.	Replace coupling.	Spares inspection.
PINION 204-040-500-9	Bending Fatigue Failure - Tooth bending fatigues through the root progressing under the rim of the gear.	Unclean material	Full progression of the bending fatigue failure will result in the loss of gear teeth and the subsequent loss of tail rotor. Pilot manuals outline procedures for reacting to the loss of tail rotor. If the loss is in flight, the situation is critical but not extremely critical. However, the loss of tail rotor in a hover is an extremely critical situation. The ultimate danger in landing the aircraft with this malfunction is the tendency of the aircraft to turn over.	The 42-degree gearbox chip detector could be of some assitance. However, the rate of progression of this failure is suspected to be quite rapid. The first indication to the pilot is the loss of his anti-torque controls.

TABLE B-3. 90-DEGREE GEARBOX FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 204-040-012-7/-13

Component	Failure Mode	Cause	Effect	Warning
INPUT COUPLING 204-040-604-5	Excessive Wear	Loss of Grease - Slipping past the se l.	The loss of grease will produce over-heating of the coupling. Overheating of the coupling is not an unsafe condition.	None
SPIRAL BEVEL GFAR 204-040-401-7	Bending Fatigue Failure	Unclean material.	The geometry of and stubbiness of the gear calls for a slow rate of progression of a fatigue failure. Consequently, debris is allowed to be an ample warning of the failure through the chip detector.	90-degree gearbox chip detector.

TABLE B-4. UH-1B/D/H MAIN ROTOR HUB FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 204-011-101-11, 204-012-101-5

Component	Failure Mode	Cause	Effect	Warning
TRUNNION ASSEMBLY 204-011-105-1	Corrosion	Corrosion - Creates pitting on the exterior surface of the trunnion.	Flight is not affected by this mode.	Condition can be observed on a daily inspection.
	Surface Compressive Failure	Pitting - of the trunnion spindles is caused by tensile cracking of high asperity contacts through the thin oil film.	Hub flapping action could be retarded slightly.	This mode of failure will be found only on the teardown of the main rotor hub.
PILLOW BLOCK 204-011-108-1	Corrosion	Corrosion - creates pitting on the exterior surface of the pillow block.	Flight is not affected by this mode.	Condition can be observed on a daily inspection.
	Loss of Torque	Loss of torque - on attaching hardware can cause elongation of bolt holes.	Slight degradation in rotor operation can be noticed.	Vertical vibration in the region of the main rotor hub can be noticed.
BEARING 204-011-110-3	Excessive Wear	Wear - is a normal mode of deterioration. Wear can also be accelerated by insufficient lubrication, overstress, or excessive heat.	Slight degradation in rotor operation can be noticed.	A vertical vibration of 1/rev can be noticed in the main rotor hub.
	Overheat	Overheat - is caused by insufficient lubrication or excessive loading.	Slight degradation in rotor operation can be noticed. Overheat can cause excessive bearing wear.	If a failure is evident in flight, a vertical vibration in the main rotor hub can be noticed. Otherwise, on teardown the bearing will be found to be discolored.
	Surface Compressive Failure	Pitting - is caused by tensile cracking of high asperity contacts through the thin oil film.	No degradation in rotor operation can be noticed.	No warning of this mode will be found. Condition will be discovered on teardown.
	Debris Damage	Debris Damage - is caused by ingestion of particles such as metal flakes, metal chips, etc.	Component can undergo scoring resulting in excessive wear forcing a premature removal of the component.	Condition can be observed on teardown.
BEARING 204-011-111-1	Excessive Wear	Wear - is a normal mode of deterioration. Wear can also be accelerated by insufficient lubrication, overstress, or excessive heat.	Slight degradation in rotor operation can be noticed.	A vertical vibration of 1/rev can be noticed in the main rotor hub.
	Overheat	Overheat - is caused by insufficient lubrication or excessive loading.	Slight degradation in rotor operation can be noticed. Overheat can cause excessive bearing wear.	If failure is evident in flight, a vertical vibration in the main rotor hub can be noticed. Otherwise, on teardown the bearing will be found to be discolored.

TABLE B-4. - Continued

Component	Failure Mode	Cause	Effect	Warning
	Surface Compressive Failure	Pitting - is caused by tensile cracking of high asperity contacts through the thin oil film.	No degradation in rotor operation can be noticed.	No warning of this mode will be found. Condition will be discovered on teardown.
	Debris Damage	Debris Damage - is caused by ingestion of particles such as metal flakes, metal chips, etc.	Part can undergo scoring resulting in excessive wear forcing a premature removal of the component.	Condition could be observed on teardown.
	Fatigue Failure	Breakage - is caused by an overload or by a material failure.	Rollers and cages can break causing a stiffness in the pitch change controls. Excessive vibration in the main rotor hub of 1 per/rev will be noticed.	Excessive vertical vibration in the region of the main rotor hub can be noticed. If vibration increases, pilot should take the usual precautionary landing. If pilot should ignore the vibration, the bearing could sieze causing the loss of pitch change control, an unsafe condition. There is adequate time for landing as evidenced by the fact that no accident has resulted from failure of this bearing.
BEARING 204-011-112-1	Excessive Wear	Weak - is a normal mode of deterioration. Wear can also be accelerated by insufficient lubrication, overstress, or excessive heat.	Slight degradation in rotor operation can be noticed.	A vertical vibration of 1/rev can be noticed in the main rotor hub.
	Overheat	Overheat - is caused by insufficient lubrication or excessive loading.	Slight degradation in rotor operation can be noticed. Overheat can cause excessive bearing wear.	If failure is evident in flight, a vertical vibration in the main rotor hub can be noticed. Otherwise, on teardown the bearing will be found to be discolored.
	Surface Compressive Failure	Pitting - is caused by tensile cracking of high asperity contacts through the thin oil film.	No degradation in rotor operation can be noticed.	No warning of this mode will be found. Failure will be discovered on teardown.
	Debris Damage	Debris Damage - is caused by ingestion of particles such as metal flakes, metal chips, etc.	Part can undergo scoring resulting in excessive wear.	Condition can be observed on teardown.
	Fatigue Failure	Breakage - is caused by an overload o. by a material failure.	Rollers and cages can break causing a stiffness in the pitch change controls. Excessive vibration in the main rotor hub of 1 per rev will be present.	Excessive vertical vibration in the region of the main rotor hub can be noticed. If vibration increases, pilot should take the usual precautionary landing. If pilot should ignore the vibration,

TABLE B-4. - Continued

Component	Failure Mode	Cause	Effect	Warning
	Fatigue Failure (Cont'd)			the bearing could seize causing the loss of pitch change control, an unsafe condition. There is adequate time for landing as evidenced by the fact that no accident has resulted from failure of this bearing.
PITCH HORN ASSEMBLY 204-011-120-5	Corrosion	Corrosion - creates pitting on the exterior surface of the pitch horn.	Return the pitch horn assembly for rework. Flight is not affected by this mode.	Condition can be observed on a daily inspection.
	Loss of Torque	Loss of Torque - on attaching hardware can cause looseness and elongation of bolt holes.	Slight degradation, if any, can be noticed in the aircraft performance.	Condition can be observed on a daily inspection. May cause a noticeable vertical vibration during flight.
GRIP ASSEMBLY 204-011-121-1	Erosion	Erosion - is caused by such particles as sand, grit, etc.	Foreign particles can produce scoring of the grip surface. No degradation in aircraft performance can be noticed.	If scoring is on an external surface, then the condition can be observed on a daily inspection. If scoring is on an internal surface, then the condition can be observed on teardown.
	Corrosion	Corrosion - creates pitting on the surface of the grip. Fretting corrosion is also created due to dissimilar metals in the grip assembly.	Flight is not affected by this mode.	Surface corrosion can be observed on a daily inspection. Fretting corrosion can be observed on a teardown.
GRIP ASSEMBLY 204-011-121-5	Erosion	Erosion - is caused by such particles as sand, grit, etc.	Foreign particles can produce scoring of the grip surface. No degradation in aircraft performance can be noticed.	If scoring is on an external surface, then the condition can be observed on a daily inspection. If scoring is on an internal surface, then the condition can be observed on teardown.
	Corrosion	Corrosion - creates pitting on the surface of the grip. Fretting corrosion is also created due to dissimilar metals in the grip assembly.	Flight is not affected by this mode.	Surface corrosion can be observed on a daily inspection. Fretting corrosion can be observed on a teardown.
BEARING HOUSING LINER 204-011-130-1	Corrosion	Corrosion - creates pitting on the surface of the bearing housing liner.	Flight is not affected by this mode.	This failure mode can be found on teardown of the main rotor hub.
	Debris Damage/ Erosion	Debris Damage - is caused by a bearing failure or by foreign particles.	Flight is not affected by this mode.	This failure mode can be found on teardown.
ROD END CLEVIS 204-011-142-3	Corrosion	Corrosion - creates pitting on the surface of the clevis.	Flight is not affected by this mode.	This condition can be observed on a daily inspection.

TABLE B-4. - Concluded

Component	Failure Mode	Cause	Effect	Warning
	Loss of Torque	Loss of Torque - on attaching hardware can cause elongation of holes.	Slight degradation in rotor operation may be present.	Condition can be observed on a daily inspection. Vertical vibration in the region of the main rotor hub may be noticed.
THREADED END ROD 204-011-143-1	Corrosion	Corrosion - creates pitting on the surface of the rod.	Flight is not affected by this mode.	This condition can be observed on a daily inspection.
	Maintenance Error	Damaged Threads - are caused by improper installation or removal.	Flight is not affected by this mode.	This condition can be observed on teardown.
ROD END CLEVIS 204-011-179-1	Corrosion	Corrosion - creates pitting on the surface of the clevis.	Flight is not affected by this mode.	This condition can be observed on a daily inspection.
SLEEVE BUSHING 204-010-413-27	Corrosion	Corrosion - is caused by wear of the sleeve bushing. The wear will produce fretting in the sleeve bushing and due to dissimilar metals corrosion will be established. (Fretting corrosion) Corrosion in turn can create pitting of the sleeve bushing.	Slight degradation in rotor operation may be noticed.	This condition can be observed on teardown. A slight vibration due to looseness (wear) might be observed.
SLEEVE BUSHING 204-010-413-29	Corrosion	Corrosion - is caused by wear of the sleeve bushing. The wear will produce fretting in the sleeve bushing and due to dissimilar metals corrosion will be established. (Fretting Corrosion) Corrosion in turn can create pitting of the sleeve bushing.	Slight degradation in rotor operation may be noticed.	This condition can be observed on teardown. A slight vibration due to looseness (wear) might be observed.

TABLE B-5. UH-1C/AH-1G MAIN ROTOR HUB FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 540-011-101-5/-9

Component	Failure Mode	Cause	Effect	Warning
HOUSING ASSEMBLY 540-011-106-5	Corrosion	Corrosion - is caused by the environment and is due to improper preparation of the material. Corrosion also creates pitting.	This mode has no effect on rotor operation. Housing assembly is removed and sent for rework or scrap.	Condition may be observed on a daily inspection. Otherwise, it will be found on teardown inspection.
BEARING 540-011-110-9/-11/-13	Excessive Wear	Wear - is a normal mode of deterioration of this bearing.	As wear advances, a slight degradation in rotor operation can be noticed.	Excessive vertical vibration in the region of the main rotor hub can be noticed during operation.
	Overheat	Overheat - is caused by an overload or by deterioration of the teflon.	Slight, if any, degradation in rotor operation can be noticed.	This condition will be found on teardown.
	Erosion	Erosion - is caused by such particles as sand, grit, etc.	Erosion causes scoring of the bearing surface. No degradation in rotor operation can be noticed.	This condition will be found on teardown.
	Torn	A tear - is caused by a flaw in the teflon or by the deterioration of the teflon. The deterioration can be precipitated by overheat, erosion, wear, etc.	Degradation of rotor operation, in relation with the missing teflon, can be noticed. The degradation will be in the form of an excessive 1/rev vertical vibration in the region of the main rotor hub.	Excessive vibration correlating to the amount of teflon missing can be noticed. If vibration increases, the pilot will make the usual precautionary landing. If the vibration is ignored, a violent 1/rev vibration will be felt. If this deterioration is ignored and metal-to-metal contact is established in the bearing, the bearing could seize. If the bearing seizes, pitch control would be lost, an unsafe condition. Seizing will probably not occur as long as the 1500 pounds of hydraulic pressure are still assisting as a boost. As evidence of the improbability of the event, there is no record of this bearing being the cause of a forced landing, much less a crash.
CLEVIS 540-011-117-1/-3	Corrosion	Corrosion - creates pitting on the exterior surface of the clevis.	No degradation in rotor operation can be noticed.	This condition can be observed on a daily inspection.
	Loss of Torque	Loss of Torque - on attaching hardware can cause elongation of holes.	Slight, if any, degradation in rotor operation can be noticed.	Excess play may be observed during daily inspection. Vertical vibration in the region of the main rotor hub may be noticed.

TABLE B-5. - Continued

Component	Failure Mode	Cause	Effect	Warning
CLEVIS 540-011-117-2 (Part of 540-011-101-9 assembly only)	Corrosion	Corrosion - creates pitting on the exterior surface of the clevis.	No degradation in rotor operation can be noticed.	This condition will be observed on a daily inspection.
	Loss of Torque	Loss of Torque - on attaching hardware can cause elongation of holes.	Slight, if any, degradation in rotor operation can be noticed.	Excess play may be observed during daily inspection. Vertical vibration in the region of the main rotor hub may be noticed.
BARREL ASSEMBLY 540-011-118-1	Corrosion	Corrosion - creates pitting on the exterior surface of the barrel assembly.	No degradation in rotor operation can be noticed.	This condition can be observed on a daily inspection.
	Erosion	Erosion - is caused by such foreign particles as sand, grit, etc.	No degradation in rotor operation can be noticed.	This condition can be observed on a daily inspection.
BUSHING, MAIN ROTOR PITCH HORN 540-011-131-7	Corrosion	Corrosion - creates pitting in the bushing.	This mode does not affect rotor operation.	This condition can be observed on teardown.
	Erosion	Erosion - is caused by such particles as sand, grit, etc.	No degradation in rotor operation can be noticed.	This condition can be observed on teardown.
SLEEVE 540-011-143-9/-11/-13	Excessive Wear	Wear - is a normal mode of deterioration of the sleeve. Wear would be accelerated by overstress, excessive heat, or deterioration of the teflon surface of the bearing.	Slight degradation in rotor operation can be noticed.	Excessive vibration in the region of the main rotor hub can be noticed.
	Overheat	Overheat - is caused by an overload or by a deterioration of the teflon surface of the bearing.	No degradation in rotor operation can be noticed. Overheat can produce excessive wear necessitating the premature removal of the sleeve.	This condition will be found on teardown unless the teflon deterioration is severe, in which case the warning will be the same as in excessive wear.
	Erosion	Erosion - is caused by such particles as sand, grit, etc.	No degradation in rotor operation can be noticed. Erosion can produce excessive wear resulting in the premature removal of the sleeve.	This condition will be found on teardown unless the teflon deterioration is severe, in which case the warning will be the same as in excessive wear.
	Corrosion	Corrosion - creates pitting in the sleeve.	No degradation in rotor operation can be noticed. Secondary damage can be produced by these metal flakes.	This condition will be found on teardown.
MAIN ROTOR TRUNNION ASSEMBLY 540-011-150-5	Corrosion Pitting	Corrosion - can create pitting on the surface of the main rotor trunnion assembly.	No degradation in rotor operation can be noticed.	This condition may be observable on a daily inspection. Otherwise, the condition will be observed on teardown.

TABLE B-5. - Concluded

Component	Failure Mode	Cause	Effect	Warning
	Deterioration	Cracking of the main rotor trunnion sleeves is caused by wear from the main rotor trunnion bearings. The sleeve wears thin and then cracks. This mode of failure can be accelerated by deterioration of the teflon surface.	Slight degradation in hub operation; that is, hub flapping action is impeded, can be noticed.	A vertical vibration in the region of the main rotor will be noticed.
	Erosion	Erosion - is caused by such foreign particles as sand, grit, etc.	No degradation in rotor operation can be noticed. Erosion can cause excessive wear resulting in the premature removal of the trunnion.	This condition will be found on teardown.
	Corrosion	Corrosion - is caused by the environment and is due to improper preparation of the component.	No degradation in rotor operation can be noticed. Return trunnion for rework.	This condition may be observed on a daily inspection. Otherwise, the condition will be discovered on teardown.
EXTENSION ASSEMBLY 540-011-153-15	Corrosion Pitting	Corrosion - can create pitting in the extension assembly.	No degradation in rotor operation can be noticed.	This condition may be observable on a daily inspection. Otherwise, the condition will be observed on teardown.
	Erosion	Erosion - is caused by such foreign particles as sand, grit, etc.	No degradation in rotor operation can be noticed.	This condition may be observable on a daily inspection. Otherwise, the condition will be observed on teardown.
	Corrosion	Corrosion - is caused by the environment and is due to improper preparation of the material.	No degradation in rotor operation can be noticed.	This condition may be observable on a daily inspection. Otherwise, the condition will be observed on teardown.
	Deterioration	Cracking of the extension assembly sleeves is caused by wear from the bearings. The sleeve wears thin and then cracks. This mode of failure can be accelerated by deterioration of the teflon surface.	Slight degradation in rotor operation can be noticed.	A vertical vibration in the region of the main rotor will be noticed.
BUSHING 540-011-161-3	Corrosion Pitting	Corrosion - can create pitting on the bushing.	No degradation in rotor operation can be noticed.	This condition will be found on teardown.

TABLE B-6. UH-1B/D/H SWASHPLATE FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 204-011-400-11

Component	Failure Mode	Cause	Effect	Warning
TRUNNION ASSEMBLY KSP 9001	Excessive Wear	Wear - is a normal mode of deterioration of this trunnion assembly. Wear can be accelerated by erosion, corrosion, overstress, etc.	A slight degradation in swashplate operation can be noticed.	Excess play may be observed during daily inspection. A vertical vibration in the region of the swashplate can be noticed.
	Corrosion Pitting	Corrosion - can create pitting of the trunnion assembly.	No degradation in swashplate operation can be noticed.	This condition can be observed on a daily inspection. If it is not observed on a daily, it can be observed on teardown.
	Erosion	Erosion - is caused by such particles as sand, grit, etc.	No degradation in swashplate operation can be noticed.	This condition may be observed on a daily inspection. Otherwise, it can be discovered on teardown.
	Corrosion	Corrosion - is caused by the environment and is a result of improper preparation of the material.	No degradation in swashplate operation can be noticed.	This condition may be observed on a daily inspection. Otherwise, it can be discovered on teardown.
LINER 204-011-425-1	Corrosion Pitting	Corrosion - can create pitting of the liner.	No degradation in swashplate performance can be noticed.	This condition can be observed on teardown.

TABLE B-7. AH-1G SWASHPLATE FAILURE MODES AND EFFECTS ANALYSIS

Assembly Part Number: 209-010-400-1

Component	Failure Mode	Cause	Effect	Warning
BEARING 204-011-430-1	Excessive Wear	Wear - is a normal mode of deterioration of the bearing. Wear can be accelerated by overheat, overstress, erosion, etc.	A slight degradation in swashplate operation can be noticed.	Excess play may be observed during daily inspection. Excessive vibration in the region of the swashplate can be noticed during operation.
	Corrosion Pitting	Corrosion - can create pitting of the bearing.	No degradation in swashplate operation can be noticed.	This condition can be found on teardown.
SUPPORT ASSEMBLY 209-010-404-1	Corrosion Pitting	Corrosion - Can create pitting of the support assembly.	No degradation in the support assembly operation can be noticed.	This condition will be found on teardown.
	Overheat	Overheat - is caused by an overload or a deterioration of the teflon surface of a bearing.	No degradation in the support operation can be noticed.	This condition will be found on teardown.
	Erosion	Erosion - is caused by such particles as sand, grit, etc.	No degradation in the support assembly operation can be noticed.	This condition may be observable on a daily inspection. Otherwise, it can be found on teardown.
	Corrosion	Corrosion - is caused by the environment and is a result of improper preparation of the material.	No degradation in the support assembly operation can be noticed.	This condition may be observed on a daily inspection. Otherwise, it can be found on teardown.

APPENDIX C. TECHNICAL MANUAL PREVENTIVE MAINTENANCE INSPECTION REQUIREMENTS

Taken from TM55-1520-221-PMI and TM55-1520-221-PMP. These requirements are typical of those covering UH-1 series helicopters.

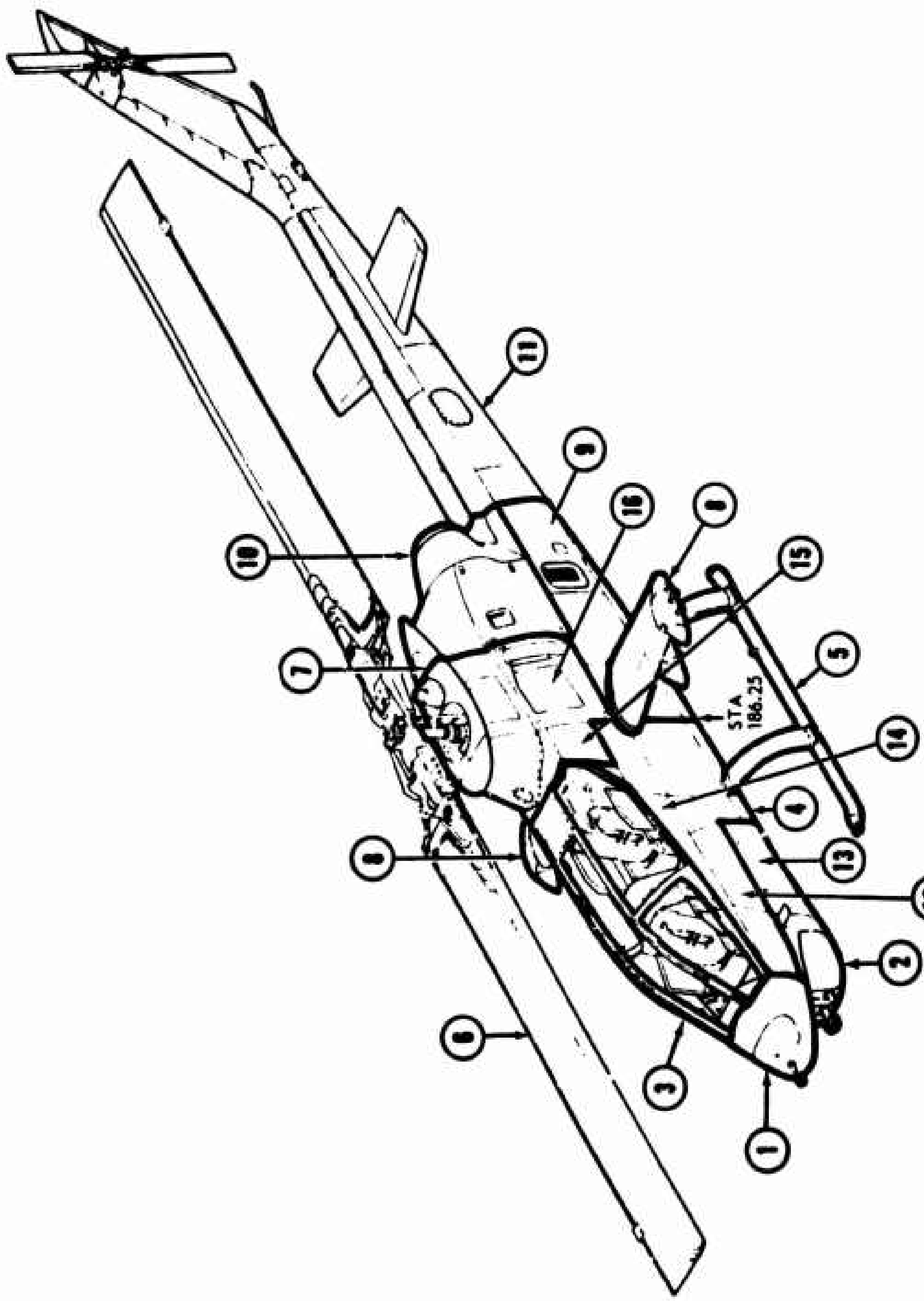


Figure C-1. AH-1G area diagram.

AREA NO. 1:	Nose Area	All surfaces, components and equipment in nose compartment and on exterior ahead of forward edge of gunners door.
AREA NO. 2:	Turret Area	All surfaces, components and equipment inside and outside of armament turret and ammunition compartment.
AREA NO. 3:	Gunner and Pilot Area.	All surfaces, components and equipment inside and outside the gunner-pilot compartment. Includes items stowed in cabin aft of pilot's seat.
AREA NO. 4:	Lower Forward Fuselage Area	All surfaces, components and equipment contained in, and on exterior of, lower forward portion of fuselage between ammunition compartment and aft cabin bulkhead (Sta 186.25) except forward fuel cell.
AREA NO. 5:	Landing Gear Area	All surfaces, components and equipment which constitute the landing gear and attachments.
AREA NO. 6:	Main Rotor Area	All components of the main rotor hub and blade. Does not include the mast.
AREA NO. 7:	Pylon Area	All surfaces, components and equipment contained in, and on the exterior of, the hydraulic and transmission compartments to the bottom of the transmission. Includes transmission cowling, mast, mounts, rotating controls, and main (input) drive shaft.
AREA NO. 8:	Wing Area	All surfaces, components and equipment in and on the wings. Includes all external fittings and attachments.
AREA NO. 9:	Center Fuselage Area	All surfaces, components and equipment in and on the fuselage below the engine deck (WL 65.00) and between the cabin area (Sta 186.25) and tail boom attachment bulkhead (Sta 299.57). Includes forward and aft fuel cells, compartment below transmission, oil cooler and compartments accessible through side doors and panels on fuselage.
AREA NO. 10:	Engine Area	All surfaces, components and equipment associated with engine installation located above engine deck (WL 65.00) and within engine cowling, tailpipe fairing, and aft fairing.
AREA NO. 11:	Tail Boom Area	All surfaces, components and equipment located in and on the tail boom and vertical fin. Includes tail rotor, synchronized elevator, control linkages, and drive train of shafts and gear boxes mounted on the tail boom.
AREA NO. 12:	Forward Fuselage above Ammunition Compartment Door	Interior and exterior surfaces, structural members and components mounted in area covered by removable panel on left side of fuselage.
AREA NO. 13:	Ammunition Compartment Door	Interior and exterior surfaces of door on left side of fuselage
AREA NO. 14:	Forward Fuselage In Area Below Pilot's Canopy	Interior and exterior surfaces on left side of fuselage.
AREA NO. 15:	Hydraulic Reservoir Access Door	Interior and exterior surfaces of door and door hinges
AREA NO. 16:	Transmission Cowling	Interior and exterior surfaces of transmission cowling on left side of fuselage

Figure C-1. Concluded.

TABLE C-1. PREVENTIVE MAINTENANCE INSPECTION REQUIREMENTS

Sequence Number	Item and Procedure
	DAILY INSPECTION
6.0	MAIN ROTOR AREA
6.2	Hub, blade grips, pitch horns, and drag braces for visible damage and security.
6.3	Sand deflectors for cracks and damage.
7.0	PYLON AREA
7.3	Swashplate, scissors, and sleeve for visible damage and security. Scissors drive link bearings for looseness or excessive play.
7.8	Transmission external oil filter bypass indicator for condition of filter element.
7.9	Transmission and connections for damage and oil leaks. Transmission sump for water contamination and oil level lift link for security. Lift link lugs for cracks with particular attention to right lift link lug in area of bushing.
11.0	TAILBOOM AREA
11.4	Intermediate (42°) gearbox for security, oil level, and leaks. Inspect gear teeth through filler cap opening for scoring.
11.5	Tail rotor (90°) gearbox for security, oil level, and leaks. Inspect gear teeth through filler opening for scoring.

TABLE C-1. - Continued

Sequence Number	Item and Procedure
	INTERMEDIATE INSPECTION
6.0	MAIN ROTOR AREA
6.2	Hub, blade grips, pitch horns, and drag braces for visible damage and security.
6.3	Sand deflectors for cracks and damage.
7.0	PYLON AREA
7.3	Swashplate, scissors, and sleeve for visible damage and security. Scissors drive link bearings for looseness or excessive play. Check control linkages for bolt wear and elongation of bolt holes. Check grips for full and free travel.
7.8	Transmission external oil filter bypass indicator for condition of filter element.
7.9	Transmission and connections for damage and oil leaks. Transmission sump for water contamination and oil level. Inspect and clean sump oil filter and chip detector. Lift link for security. Lift link lugs for cracks with particular attention to right lift link lug in area of bushing.
11.0	TAILBOOM AREA
11.4	Intermediate (42°) gearbox for security, oil level, and leaks. Inspect and clean chip detector. Check breather vent for clogging. Inspect gear teeth for scoring. (Refer to special inspection, after tail rotor drive system over-torque.)
11.5	Tail rotor (90°) gearbox for security, oil level, and leaks. Inspect and clean chip detector. Check filler cap for clogged vent. Inspect gear teeth through filler cap opening for scoring.

TABLE C-1. - Continued

Sequence Number	Item and Procedure
	PERIODIC INSPECTION
6.0	MAIN ROTOR AREA
6.3	Hub, blade grips, pitch horns, and drag braces for visible damage and security. Pitch change tube bearings for excessive radial and axial play. Rotate main rotor trunnion housing 180°.
6.4	Sand deflectors for cracks and damage.
7.0	PYLON AREA
7.3	Swashplate, scissors and sleeve for visible damage and security. Scissors drive link bearings for looseness or excessive play. Check control linkage for bolt wear and elongation of bolt holes. Check for excessive play in bearings and bushings. Partially disassemble friction collet assembly to inspect collet for condition and cracks. Detach and lift spline plate and extension up mast and lubricate mast splines and mating splines. Reassemble and adjust friction collet assembly. Check swashplate breakaway force of 17-21 pounds at control horn with swashplate disconnected.
7.8	Transmission external oil filter element replaced.
7.9	Transmission and connections for damage and oil leaks. Inspect and clean sump filter. Transmission sump for water contamination and oil level. Inspect and clean oil filter and chip detector. Chip detector for foreign metal particles. Check lift link for cracks and security. Clean and inspect lift link lugs for cracks using dye-penetrant method. Particular attention should be given right lift link lug in area of bushing. Paint must be removed in lug area to properly inspect.

TABLE C-1. - Concluded

Sequence Number	Item and Procedure
11.0	TAILBOOM AREA
11.4	Intermediate (42°) gearbox for security and oil leaks. Inspect and clean chip detector. Check breather vent for clogging. Inspect gear teeth for scoring. (Refer to special inspection, after tail rotor drive system over-torque.) Change gearbox oil.
11.5	Tail rotor (90°) gearbox for security and oil leaks. Inspect and clean chip detector. Check filler cap for clogged vent. Change gearbox oil.

APPENDIX D SPECIAL INSTRUCTIONS

Taken from TM55-1520-221-20. These instructions are typical of those covering UH-1 series helicopters.

TABLE D-1. SPECIAL INSPECTION REQUIREMENTS

Item and Procedure
<u>AFTER A HARD LANDING</u> Definition: Hard landing is defined as any accident or incident in which ground impact of the helicopter causes severe pitching of main rotor, allowing hard contact of hub with mast, or results in cracking the aft lugs of the transmission support case or noticeable yielding or cracking of fuselage pylon support structure or landing gear. This definition is confined only to those accidents not involving sudden stoppage of main rotor or tail rotor. Inspections: When a probable hard landing incident has occurred, proceed as follows: <u>f</u>. If no damage other than yielded landing gear cross tubes has been found during steps <u>a</u> through <u>e</u>, it can reasonably be decided that a true hard landing did not occur. Complete a careful Daily Inspection and return helicopter to operation if no further evidence of damage is found. <u>g</u>. If damage other than yielded landing gear cross tubes was found in preceding steps, a hard landing has occurred, and the following steps must be performed. <u>i</u>. Remove transmission. Tag assembly with reason for removal, and send to overhaul facility for evaluation. <u>k</u>. Perform thorough visual inspection of the following components, which may be kept in service if no discrepancy or obvious damage is found. Replace any damaged component. (2) Main Rotor Hub (5) 42° Gearbox (6) 90° Gearbox

TABLE D-1. - Continued

Item and Procedure
(9) Swashplate and Support Assembly
AFTER SUDDEN STOPPAGE (Power On or Power Off)
Definition: Sudden stoppage is defined as any rapid deceleration of the drive system, whether by internal seizure of the transmission or by main or tail rotor blades striking something which causes rapid deceleration or enough tail rotor damage to require replacement.
NOTE
Known or suspected contact of tail rotor with soft ground, snow, water, or dense vegetation requires this special inspection to the extent of condemning the tail rotor hub and blade assembly and conducting a progressive inspection of the tail rotor drive system. Automatic replacement of main rotor components would not be required.
Inspections: Conduct a progressive inspection, replacing components according to the following criteria.
a. Main Rotor
(2) If either blade is damaged, replace both blades and the hub assembly. Send components to overhaul for evaluation.
(3) If neither blade shows damage, and there is no obvious damage to hub, both blades and hub assembly may remain in service.
b. Main Rotor Rotating Controls
(2) Replace swashplate assembly and scissors and sleeve assembly and send to overhaul for evaluation if any of the following conditions exist:

TABLE D-1. - Continued

Item and Procedure
(a) Severe main rotor blade damage (blade bent, twisted or badly torn).
(b) Main rotor pitch horn failure.
(c) Control tube buckled or broken.
(d) Transmission main support case mounting lug broken.
d. Transmission Assembly.
(1) Replace and visually inspect transmission assembly.
(2) If mast inspection revealed torsional yielding, the transmission should be considered unserviceable and non-reparable.
(3) If mast did not show such damage, and there is not other obvious damage which makes transmission non-reparable, send transmission assembly to overhaul for evaluation.
h. Gearboxes, 42° and 90°
(1) Visually inspect removed gearboxes. If broken or mutilated so that parts cannot be salvaged, the component should be considered unserviceable and non-reparable and should be condemned locally. Otherwise, send gearbox assemblies to overhaul for evaluation.
AFTER MAIN ROTOR OVERSPEED
Inspection and/or replacements are required after any report that main rotor has exceeded 339 rpm limit. When 356 rpm has been exceeded, additional requirements apply.

TABLE D-1. - Continued

Item and Procedure
Main Rotor Overspeed Exceeding 356 RPM:
b. Replace main rotor hub assembly. Send removed hub to overhaul facility, with information on overspeed incident.
c. Visually inspect blade retention bolts and drag brace bolts for shear offset.
g. Visually inspect the following components, which may be considered satisfactory for continued use if no visible damage is found:
(1) Transmission Assembly
(2) 42° Gearbox
(3) 90° Gearbox
(7) Swashplate Assembly
AFTER EVERY 300 HOURS OF MAIN ROTOR HUB OPERATION
NOTE
The following inspection shall be performed by Direct Support personnel.
a. Remove main rotor, and remove blades. Partially disassemble hub grips and trunnions.
b. Inspect carbon radius ring on main rotor hub extension for cracks, damage, excessive wear or bonding security. Inspect extension for damaged, worn, or loose bearing sleeves.
c. Inspect hub bearing housings, bearings, and seals for condition.

TABLE D-1. - Continued

Item and Procedure
d. Inspect hub trunnion bearing housings, seals, and bearings for condition.
e. Inspect trunnion bearing housing disks for security of bonding, bearings and seals for condition.
f. Inspect trunnion spindle sleeves for security of bonding.
g. Replace unserviceable parts and reassemble hub, static balance hub and reinstall main rotor blades. Check spanwise alignment.
h. Reinstall main rotor.
AFTER A REPORTED ENGINE COMPRESSOR STALL
Engine compressor stall (surge) is characterized by a sharp rumble or a series of loud, sharp reports, severe engine vibration, and a rapid rise in exhaust gas temperature (egt), depending on severity of surge. When a surge has been reported, perform following steps.
g. If surge occurs at 85% nl speed or above: Remove and disassemble tail rotor gearbox (90°) in accordance with procedures outlined in the applicable reference manual, and inspect the drive and driven gear for unusual load pattern on either the coast or drive side of gears. Inspect area of driven gear between lightening holes and gear teeth for cracks, using a 10-power glass.
h. If, as a result of the above inspections conducted, evidence of damage is indicated, comply with the following:
(1) Remove and replace the following items with serviceable item (annotate DA Form 2410 that component had been installed on aircraft subjected to compressor stall).
(a) 90° gearbox.

TABLE D-1. - Continued
Item and Procedure
(2) Inspect the 42° gearbox output gear for unusual load pattern on either the coast or drive side of the gear. If no evidence of damage is noted, return the gearbox to service. If the above inspections reveal discrepancies, remove and replace gearbox assembly and comply with (3) below.
(3) Remove the tail rotor drive output quill assembly from the transmission and inspect gear for unusual load pattern on either the drive or coast side of the gear teeth. If no evidence of damage is found, replace the quill assembly and return the transmission to service.
j. If the above outlined inspection of the tail rotor drive output quill presents negative indications of damage, reinstall in accordance with instructions as outlined in appropriate technical manual and return helicopter to flight status. If inspection of the tail rotor output quill reveals discrepancies, remove transmission from service and return for overhaul. (Annotate DA Form 2410 as stated above.) Further, if it is found necessary to replace the transmission, conduct the following inspection of the main rotor system and the fuselage.
(1) Remove inboard and outboard drag brace bolts. Check bolts for deformation, then magniflux. If satisfactory, return to service.
(2) Remove main rotor bearing caps from main rotor flexure and check for deformation of bearing caps and attaching holes in flexure.
(3) Perform close visual inspection of all other main rotor components.
(4) If any discrepancies are noted as a result of inspection in items (1), (2), and (3), remove and replace the main rotor hub and blade assembly and mast assembly (annotate records as stated above).

TABLE D-1. - Continued

Item and Procedure
<u>AFTER EXCESSIVE ENGINE TORQUE</u>
Definition: Over-torque is defined as any incident in which torsional loads in excess of established limits are introduced into the helicopter dynamic system. An engine torquemeter indication in excess of 50 psi is considered over-torque, and special inspections are required after indication above 54 psi.
After Engine Torque Between 54 and 61 PSI: Inspect and/or replace components as follows. Records of replaced components shall show over-torque condition as reason for removal.
a. Replace main rotor trunnion cap bolts.
b. Inspect main transmission sump filter and chip detector.
(1) Positive indications are cause for replacing transmission, and sending it to overhaul for evaluation.
(2) If there are no positive indications, continue operation for five hours, then repeat inspection. If no positive indications are then found, resume normal operation.
c. Perform thorough visual inspection of the following components, which may be kept in service if no discrepancy or obvious damage is found. Replace any damaged component.
(2) Main Rotor Hub
(5) 42° Gearbox
(6) 90° Gearbox
(9) Swashplate Assembly

TABLE D-1. - Continued

Item and Procedure
After Engine Torque Above 61 PSI:
a. Replace the following components, and send to overhaul for evaluation, with records showing over-torque as reason for removal.
(1) Transmission
(5) Main Rotor Hub
b. Perform thorough inspection of the following components, which may be kept in service if no discrepancy or obvious damage is found.
(3) 42° Gearbox
(4) 90° Gearbox
(7) Swashplate Assembly
AFTER TAIL ROTOR DRIVE SYSTEM OVER-TORQUE
After any report of suspected over-torquing of the tail rotor drive system during operation, perform the following inspection as soon as possible after the incident. This procedure is used also for scheduled inspections when there is no recorded operational incident.
a Remove oil filler cap from 42° gearbox, and inspect output gear teeth for scoring as described in Chapter 7. If no scoring is found, no further inspection is necessary. If gear teeth are scored, replace gearbox assembly and perform step b.
b. Remove filler cap from 90° gearbox, and inspect condition of gears as in step a. If scoring is found, replace gearbox assembly and perform step c.

TABLE D-1. - Concluded

Item and Procedure
c. Remove transmission tail rotor drive quill and inspection condition of gear teeth. Evidence of scoring is cause for replacement of transmission assembly.
d. Tag any removed components with reason for removal before turning in through normal supply channels for overhaul.

APPENDIX E TEST FLIGHT INSPECTION REQUIREMENTS

Takens from TM55-1520-221-20. These instructions are typical of those covering UH-1 series helicopters.

TABLE E-1. AIRCRAFT TEST FLIGHT INSPECTION CHECKSHEET INSTRUCTIONS

Item No.	Inspection Items
	GROUND CHECK
6	Engine run-up
	c. Transmission oil pressure - Check for indication
	CAUTION
	If no oil pressure is evident at this time, shut the engine down immediately and investigate the cause.
	d. Master caution light - OFF.
	i. Caution panel lights - Check all out, master caution out.
	s. Transmission oil pressure: 30 min., 70 max.
	t. Transmission oil temperature: 100°C max.
	ah. Cyclic and collective - Check freedom of movement; note HYD PRESS No. 1, warning light on caution panel. Pedal movement stiff.
	ax. List for any abnormal noises.
	INFLIGHT CHECK
1	Takeoff to Hovering
	a. Engine for specified:
	(4) Transmission oil pressure (psi): 40 min., 60 max.

TABLE E-1. - Continued

Item No.	Inspection Items
	(5) Transmission oil temperature. 110°C max.
	b. Helicopter for control, stability, proper response to control forces.
	(1) Cyclic response - Move various directions and observe tip path for proper movement.
	(2) Collective pitch response - Increase slowly, noting that CG feels normal, until at a hover.
	c. Flight characteristics -
	(3) Rearwards and forward flight to check cyclic response.
2	In-flight Check
	a. Engine for specified:
	(4) Transmission oil pressure (psi). 40 min., 60 max.
	(5) Transmission oil temperature. 110°C max.
	e. Make autorotation at 60 knots.
	(4) Note rotor RPM - Do not let exceed limits. At average ambient conditions and light gross weight, ship should develop 305 to 310 RPM. Note vibrations.
	g. Check control position and forces. Check that force trim will hold controls in position.

TABLE E-1. - Concluded

Item No.	Inspection Items
	i. Investigate rotor vibrations. (Record adjustments of rotor smoothing procedure.)
	(1) Slow to 70 knots and make descent. Note any 1/rev vibration.
	(2) Level off and slow to 40 knots then increase airspeed slowly up to Vne (unless vibrations get uncomfortably severe). Note any 1/rev vibration and airspeed at which it became evident. Note any excessive 2/rev vibration or higher frequency vibrations.
	(3) Slow aircraft and accomplish a zero airspeed out of ground effect hover. Note sufficient left pedal available. Note any 1/rev vibration.
	AFTER FLIGHT CHECK
1	Reduce power to flight idle position prior to shutdown, allowing engine to operate at flight idle for 1-2 minutes, and observe the following readings:
	(5) Transmission oil temperature. 110°C max.
	(6) Transmission oil pressure (psi). 30 min., 70 max.
3	Engine coast-down time minimum 25 seconds.

GLOSSARY

1. Accident - Damage to one or more aircraft which occurs between the time the engine(s) is (are) started for the purpose of commencing flight until the time the aircraft comes to rest with all engines and propellers or rotors stopped. (AR-385-40)

2. Allowable Operating Life (AOL) - The specified periods of operating time when items of equipment with limited fatigue life are scheduled to be replaced and discarded.

3. Component/Assembly - A number of parts or subassemblies or any combination thereof joined together to perform a specific function and capable of being disassembled. (MIL-STD-280A)

4. Critical Part - A part or assembly with any failure mode which would result in loss of subsystem function and could result in an unsafe condition.

5. Failure Mode - A way in which the failure of an item can occur.

6. Failure Rate/Hazard Rate - The number of occurrences per unit measure of life for which an item is unable to perform its required function within previously established limits. (MIL-STD-721A)

7. Forced Landings or Worse Mishaps - The classes of mishaps for which aircraft damage occurs and/or for which a landing is immediately necessitated by a failure or condition which makes continued flight impossible.

8. Induced Failure Mode - A failure basically caused by a physical condition or phenomenon imposed on an item of equipment and for which the equipment was not designed.

9. Inherent Failure Mode - A failure basically caused by a physical condition or phenomenon which is normal to the equipment and for which it should have been designed.

10. Mishaps - Any occurrence or equipment condition which interrupts or terminates a mission prematurely or causes aircraft damage. (Normally combat damage is excluded.)

11. On-Condition Maintenance - Restoration of an item to serviceability as required without regard to specified overhaul periods.

12. Part - One piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of the designed use. (MIL-STD-280A)

13. Precautionary Landing - A landing necessitated by failure or apparent impending failure of engines, systems or components which makes continued flight inadvisable, and which did not result in damage. (AR 385-40)

14. Scheduled Overhaul - A specified point in operating time when items of equipment are scheduled to be removed from service for disassembly, inspection, and the replacement of parts no longer acceptable.

15. Time Between Overhauls (TBO) - The maximum time that an item is permitted to operate between scheduled overhauls.

16. Sequential Overhaul Records - Records of the first and subsequent assembly overhauls arranged in a chronological order.